THE CENTER FOR ROBOTICS DEVELOPMENT

MATE ROV COMPETITION

ROBOCENTER

COMPANY

TECHNICAL REPORT

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THE CENTER FOR ROBOTICS DEVELOPMENT, VLADIVOSTOK, RUSSIA, 2022

CONTENT

Annotation

Picture 1 - Photo of the assembled ROV Tercel

Our Robocenter team consists of 10 participants of grades from 8 to 10 from different schools in Vladivostok, Russia. We represent the Center for Robotics Development and have been participating in MATE competitions for 8 years. Our team participates in the contest in order to promote engineering and robotics among children.

MATE challenges students around the world to solve the problems of the underwater world. MATE distinguished three missions: Marine renewable energy, Offshore aquaculture and blue carbon, Antarctida then and now.

This year our team has developed a new ROV called "Tercel" which is completely different from last year. To create it, we assigned roles and responsibilities. We also developed a plan for its creation, made a Gantt chart, drew up protocols and procedures, paid attention to financial accounting and safety

We've developed and manufactured special payload for our ROV:

- The rear hook is used to carry the patch and draw out the growths.
- Profiling drift based on buoyancy engine.
- Software for performing tasks on automatic swimming and measurement.

We're pleased of the updates of our ROV this year:

- The new microcontroller provides more stable operation and faster loading of the ROV.
- We've increased the cross-section of the tether, which has increased the stability of operation.
- The new frame increased the speed and maneuverability of the ROV.
- Replacing 8 thrusters with 6 reduced the total cost of the ROV and increased the onboard voltage.

And we express our gratitude to everyone who helped us with physical and material resources in the process of creating ROV.

Teamwork

Robocenter Company

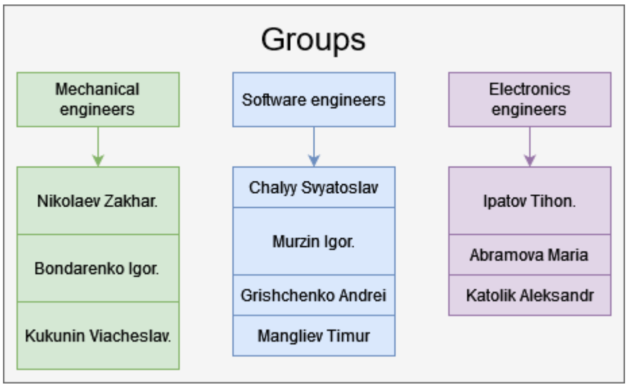
1. Company profile

The Robocenter company was founded in 2014 in Vladivostok. We specialize in developing and manufacturing remote-operated uninhabited underwater vehicles (ROV) and related systems.

Our goal is to win the MATE ROV Competition [1]. We want to do this to make our parent organization, the Center for Robotics Development (CfRD) more famous. We consider it important because the CfRD is engaged in the promotion of robotics and engineering creativity among children.

To do this, for the 7th year in a row, we accept a challenge from MATE ROV Competition to create a ROV. This year MATE gave a request to create a ROV to solve problems of marine renewable energy, aquaculture and blue carbon, as well as the study of Antarctica [1].

Picture 1 - Team. From left to right: Svyatoslav, Tikhon, Zakhar, Timur, Igor B, Andrey, Masha, Igor M, Sasha



Picture 2 - Roles in the team

2. Staff

This year we hired 10 volunteers among students of grades 8-10 from different schools in Vladivostok. Each participant has individual qualities that are taken into account when choosing a role in the team. Not all participants are newcomers, some participants have been in the team since last year. They already know the necessary things, so they can start work earlier, and they can also share their experience with other participants.

In the development and production of ROV, the roles of participants are divided into three groups: mechanical engineers, electronics engineers and software engineers. Mechanical engineers are engaged in the development of the design of the ROV and its components, electronics engineers are engaged in the maintenance and design of the electrical components of the ROV and payload, programmers are engaged in the development of software for working with the ROV.

We have a limited number of participants. Therefore, almost everyone performs administrative and executive roles in addition to development roles.

Work plan and development schedule ROV

After the creation of the team in October 2021, we drew up a pre-competition work plan in Gantt chart format. To estimate the time to complete certain tasks, we studied the history and experience of our team, as well as other teams from their technical reports. The plan is in the attachment.

In the gantt chart, we added the time for which we completed any task. This way we can see how different our plan is from what we have done.

To maintain the ROV development schedule, we used various technologies and tools, which are described below.

Role	Person
CEO	Zahar Nikolaev
CFO	Tihon Ipatov
Graphic Designer	Zahar Nikolaev
Media Relations Specialist	Igor Murzin
Safety Specialist	Bondarenko Igor.
Chief Pilot	Tihon Ipatov
Co-pilot	Mariia Abramova
Cable Manager	Igor Murzin
Prop manager	Bondarenko Igor

Table 1 - Distribution of positions in the team

Resource, process and protocol management

Resource management

In our company, we distinguish 3 categories of resources: labor, financial and production. The most important of these resources is the labor force, which is why we have been most careful in managing working hours. The working time management process is described below.

We have appointed a financial director to manage financial resources. He was responsible for the accounting and distribution of finances in the team. For more information about working with finances, see the Accounting section.

Our company has access to a limited amount of production equipment. So, for example, employees of the electronics department coordinated with each other the procedure for assembling printed circuit boards and installing them on ROVs to distribute the time for access to soldering equipment.

Processes within the company

To maintain the development schedule, we have a process for monitoring work in progress. The cycle of the process of monitoring the work in progress is as follows.

At the meeting every Friday, we determined the list of tasks for the coming week. On Tuesday we have a short review meeting to see what has been done. If the work was not done, then we looked for the reasons that prevented the task from being completed before this meeting. After we have found the cause, we determine what needs to be changed to meet the deadline.

Protocol management

Logs are needed to track progress, record results, and identify errors in recurring events. We identified three events that require accurate logging: meetings, ROV testing, and training sessions. We have developed our own protocol for each of them.

During each meeting, logs are recorded, which include the following items:

- Personal report on the work done;
- The number of hours worked by each employee;
- Expenses per week;
- Choosing a priority task and determining the timing of its implementation.

We will familiarize ourselves with the rest of the protocols in the relevant sections.

ROV design rationale

To make a good ROV our team determined the plan for its creation.

Development plan:

Our team explored the Ranger Competition Manual [1] to develop a Usage model of the ROV. The actual Usage model is included in the application. With it we understood which tools we needed to solve mission problems.

Having determined the approximate dimensions and weight of the payload, we came up with its layout. Thanks to this, we were able to develop a propulsion system. After that we developed the Control system taking into account energy consumption and mission tasks.

To unite all systems together, we have developed a carrier system consisting of a frame, buoyancy and ballast. Having developed the frame design, we ordered its manufacture at the Robotics Center. At the same time, the thrusters and cameras were sealed, and the components were prepared for installation. We also started making payloads. After that we started assembling ROV.

Innovations 2022

In order to improve the efficiency of our ROV relative to last year's ROV, we have made some changes to its various systems:

- Larger cable reduces voltage drop. Due to this, we have significantly improved the stability of the on-board electronics and increased the speed of the ROV in the water.
- Reducing the number of vertical motovers from 4 to 2, reducing the cost and weight of ROV as a whole.
- Placing the enclosure vertically reduced the size and water resistance of the ROV, therefore we got better maneuverability.
- Placing one of the rotating cameras on the bottom uses it as a bottom camera without losing the rear camera functionality. Thanks to this, we reduced the number of needed cameras by 1, which reduced the cost of ROV.
- Replacing the manipulator with a new cheaper version made it possible to reduce the cost of the ROV as a whole and make it more reliable.

Build vs. buy, new vs. used

To make a decision on **trade-offs**, we had a special strategy, which is described below. Our company is participating not for the first time, consequently we have a stockpile of parts. When choosing solutions for our ROV for this year, we have defined what can be reused and what can be made or bought.

	Component	Explanation
Build	Frame	Since the store does not have the frame we need, we had to design it ourselves
	Gripper	The production is very easy and does not require great reliability, it is also difficult to find such a grip in the store.
	Hooks	The production is very simple, allowing the hooks to do their work.
	Remote Control	We're using last year's team's remote control. Since last year's team didn't have the right remote control in the store, they had to make it themselves.
Buy	Thrusters	The production is very complex, high requirements for reliability and technological process
	Manipulator	The production is very complex, high requirements for reliability and technological process

	Component	Explanation
New	Hooks	Making new hooks is very easy and does not require much effort.
	Gripper	A new actual load that we have created to complete missions faster this year.
	Manipulator	Since the old one is in poor condition, we bought a new one. The new one has better grip and better durability, and is also easier to manage.
Used	Cameras	We used the old ones, because we did not see the point in the new ones, since the old ones are in good condition
	thrusters	New motors are expensive, and the old ones are working well enough.
	Remote Control	The remote control performed well last year and is performing well this year.

Table 2 - Made, purchased, new and old components

Problem solving

All the time working with the ROV, we faced problems that were difficult to solve. To deal with them, we needed to understand whether the reason is our incompetence, lack of experience, or this problem requires an original / new solution. We **brainstormed**: if some product was needed to solve a problem, then we studied analogues and tried to find the most profitable offer or make it ourselves, read scientific articles and technical reports of other teams for previous years [6], discussed the problem. If we could not find a solution on our own, we turned to mentors.

For example, during the first training in the pool, the vehicle stopped responding to commands from the remote control. We **brainstormed** it. The team came together to isolate the problem. Each department came up with their own ideas of what could go wrong. Having compiled a list of hypotheses, we turned to the Decision Making Algorithm, which is indicated in the Critical Analysis section. According to this algorithm, we found out that the matter was in the damaged conductor of the tether.

Construction

To separate tasks within the team, we have defined 4 systems:

- Carrier system
- Propulsion system
- Payload
- Control system

The Design of the ROV

The exceptional design of our ROV was developed in order to increase the main properties, such as speed, maneuverability, increase the range of visibility of cameras, as well as the possibility of rational placement of the payload. Also we have payload elements such as: rear hooks with mesh, and a clamp. These elements help the ROV to perform tasks related to the transportation of marine objects much faster and more efficiently, without resorting to the use of a manipulator. In addition, our design meets safety requirements and facilitates the process of transportation and operation of the underwater vehicle.

Picture 3 - Photo of the assembled ROV Tercel

Propulsion system

Layout of the thruster system

The type of thrusters used are electric motors with a propeller. We chose this type of thrusters because electric motors are more convenient to operate than hydraulic and pneumatic machines, and the propeller will allow us to achieve greater thrust compared to the propeller wheel with the same dimensions.

We have installed 6 of MUR Thruster 1500 thrusters [3].

Horizontal plane:

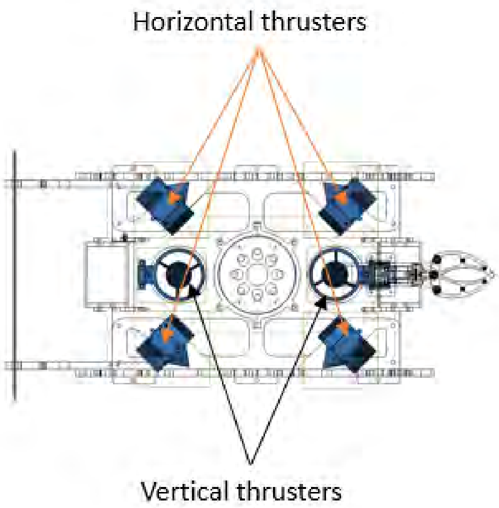
4 thrusters are designed to move the ROV in a horizontal plane and to change course. We placed them around the geometric center of mass at an angle of 45 degrees to the diametral plane. Such placement gives us the opportunity to move evenly in any direction, which is necessary for:

- reducing the number of operations during maneuvering;
- performing a cable inspection task when it is necessary to move along the cable;
- completing a task with an inspection of a marine enclosure for aquaculture.

Vertical plane

We measured the thrust of the selected thrusters on a special stand. We analyzed the weight of the props and came to the conclusion that there is enough power from two thrusters for vertical movement. Power of the thrusters on the new ROV is sufficient to lift a load of 20 N. This is enough to lift the heaviest prop - a cable weighing 10 N. At the same time, any object that we will take into the manipulator or into the payload will change the trim of the ROV. Therefore, we placed vertical thrusters in the nose and stern of the ROV to adjust the trim.

Picture 4 - Thruster "MUR Thruster 1500"



Picture 5 - Location of the thrusters on the ROV.

№	Motors	Supply voltage range	Maximum current consumption	Trust at 16V		Price	Delivery time
				Straight	Reversional		
1	MUR Thruster 1500	12-26 V	30 A	14,7 N	12,7 N	$242	Within a week
2	MUR MiddleROV Thruster	12-24 V	16 A	14,7 N	11,8 N	$242	Within a week
3	Chasing M2 Thruster	12-24 V	16 A	14,7 N	11,8 H	$242	1,5 Month
4	Chasing Gladius mini	12-24 V	16 A	14,7 N	11,8 N	$70	1,5 Month
5	T-200 Thruster	7-20 V	32 A	51,5 N	40,2 N	from $259	1-2 Month
6	IPX8	3-6 V	15 A	14,7 N	11,8 N	from $50	1,5 Month
7	DD TD1.2	12-24 V	13 A	11,8 N	9,8 N	from $85	1,5 Month
8	DD TD14	11-25 V	30 A	137,3 N	98 N	$426	1 Month

Table 4 - Characteristics of thrusters

Thruster selection trade-offs

We started designing the ROV propulsion system by choosing the propulsion model. The choice of thrusters for our ROV is limited by the maximum current of 25 A supplied by the MATE power supply, as well as their maximum thrust at this current.

At first we were thinking about replacing them. To do this, we analyzed the underwater thrusters market. But we are facing problems with logistics this year. Because of this, we realized that we would not have time to buy other manufacturers' thrusters for testing on our new ROV.

Picture 6 - Underwater thrusters' properties measurement

Name	Weight
Cable	10 N
Buoyancy module	5 N
The Hydrophone	5 N
Mort	5 N
GO-BGC Float	5 N
Seagrass	5 N
The Ghost Net	5 N
Total	35 N

Table 3 - Weight layouts

Carrier system

The carrying system of our ROV consists of a frame, mounts, buoyancy and ballast.

ROV frame

To merge the ROV components, we needed a support structure. Each participant offered his own frame concept. We chose the frame by evaluating and voting among the proposed options.

Picture 7 - Parts for frame assembly after CNC production

Picture 8 - Members' Frame Projects

Buoyancy and Ballasting System

When we put the ROV in the water, we realized that it was sinking. This behavior complicates the pilot's work, so we added additional buoyancy modules. They consist of extruded polystyrene, the density of which is much less than the density of water. Therefore, according to the Archimedes force, they are pushed to the surface. Buoyancy is located at the top of the frame to increase stability, as buoyancy pulls the vehicle up.

We used lead weights to ballast the ROV. With them, we brought the buoyancy of the ROV to neutral, and also balanced the roll and dispersed.

Payload

To complete the missions, we used the additional payload shown below.

Cameras

The ROV has 2 analog rotary cameras, MUR Rotate Camera [4]. We used analog cameras as they are cheap and easy to use. Also, the signal has a lower delay compared to digital, since the analog signal goes directly to the pilot's screen, bypassing the complex conversion for transmission through digital communication channels.

We used rotating cameras to change the angle of view when performing a specific task for more comfortable piloting.

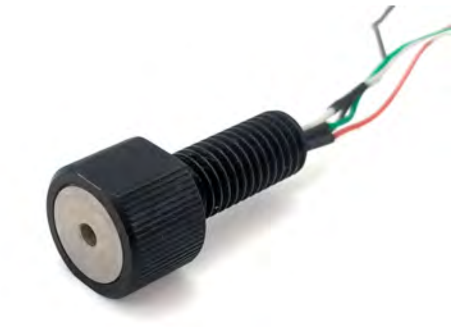
One camera is located on the top, on the front side, where the manipulator, gripper and hook are located. We use the front camera to work the main payload: the manipulator and the gripper.

Picture 9 - Camera

The second camera chamber is located at the bottom, on the back side, where the rear hooks are located. We use the rear rotary camera to see what's happening behind and also look down.

Sensors

In order for the ROV to orient itself in space, we use an IMU. It allows you to track the pitch / trim angle and understand the direction of the ROV. This is necessary, for example, for automatic navigation on a vertical grid.
We also use the MUR Depth sensor [5] to keep track of how deep in the water the vehicle is. These sensors are used for automatic control of the vehicle in tasks with transect lines and docking with swimming to the garage.
In addition to performing tasks, sensors help the pilot to control the ROVin control. So, they are used for various regulators, for example, to stabilize the ROV in depth.



Picture 10 - Depth sensor

Rear mesh hooks

Hooks are installed on the back of the ROV, on which a mesh is stretched. Hooks are used for pipe replacement tasks. They allow you to transfer a new section of cable without using the manipulator. The grid allows you to pull out pins faster, since it is easier to hook them on the grid than on a hook or manipulator.

Picture 11 - Rear mesh hooks on ROV

Picture 12 - Gripper

Gripper

The gripper is used in tasks with a buoyancy module and a hydrophone. It clamps them between its claws, which allows them to be moved. The grip is made on the basis of a solenoid. When you apply current to it, the grip is released.

Manipulator

Our team uses the manipulator as the main tool for completing missions. With it, you can conveniently capture and move objects in space. This year our team decided to replace the old manipulator. The new manipulator is called "MUR Arm Gripper", the team bought it as a set of separate components from the Robotics Center, and subsequently assembled it itself. It turned out to be cheaper than buying an already assembled one.

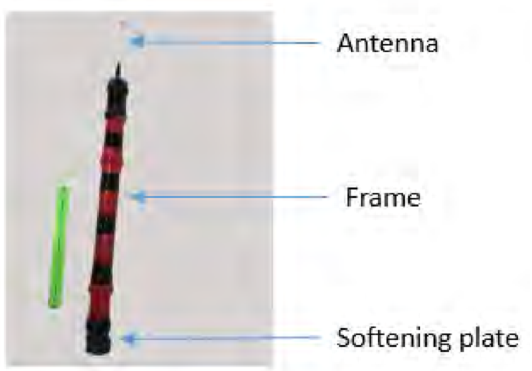
Our team decided to replace last year's manipulator, as its resource of use has been exhausted and it has become unreliable. Also, the new manipulator is lighter, smaller and cheaper.

Picture 13 - Manipulator

Float

To complete the task with the launch of the float, MATE suggested that the teams make a profiling buoy. To get the most points, a float with a buoyancy engine was needed, so we made the simplest buoyancy engine module. It is a syringe that releases and absorbs water, so that the average density of the buoy changes. The piston moves with the help of a motor and a worm gear. And it tracks its position in the water thanks to sealed buttons-hall sensors [9]. Thus, it can track when the ROV released it and then and when it touched the bottom.

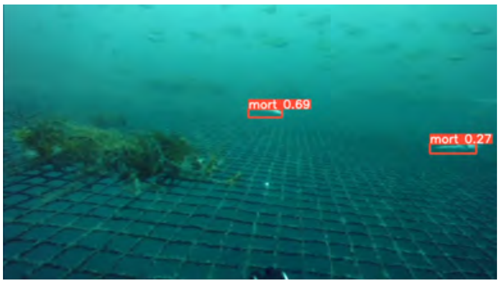
Picture 14 - Float mechanism



Picture 15 - Assembled float (90 cm)

Control system

Fish detection software



Picture 16 - AI detecting mort

We developed an AI-based program for detecting morts on video. It was made in a hurry the night before regional competitions by the joint efforts of our team. A part of the team made the dataset from videos provided by MATE, while programmers were finding the best models to use for the AI.

Surface Equipment

The first thing you need to control ROV is the input and output devices, and something that will transmit commands from these devices to ROV. We use ground equipment as these devices. It includes a joystick, a computer and an external monitor. To control the ROV, we use the ThrustMaster T Flight Hotas X joystick, as it has the necessary number of axes and buttons to control the payload. To send commands to the ROV and communicate the necessary information to the user, we use the remote control. It includes:

- Intel NUC Computer .
- Monitor to display all the necessary information on it.
- Video capture for outputting analog video to a digital monitor.
- Connectors for powering the ROV and a computer and for outputting analog video to an external monitor.
- Ampere-voltmeter for measuring voltage and current indicators supplied to the ROV.
- Moisture-resistant protective case for safe carrying of the remote control near water.

The Surface Equipment also includes upper software. The software is based on the Qt framework, which is installed on the control panel. Her task is to read
data from the control panel and send data to the lower software, and also display the image on
pilot screen.

Picture 17 - Surface Equipment

We are using a second external monitor so that we can run additional programs in parallel.

A computer with Ubuntu installed on it is installed in the remote control, thanks to which it can be used not only to control the ROV, but also for other tasks. So, on the remote you can run various programs to complete tasks, as well as safely use it to write software and technical documentation.

Electronics block

To control the payload and thrusters, as well as collect data from cameras and sensors, we need an electronics unit. For these purposes, we use the on-board electronics module with HighROV [7] kit. Based on the experience of last year, due to the fact that the Raspberry Pi uses a lot of power electricity, and also took a very long time to start up, we decided to use a microcontroller rather than a microcomputer [11]. In the absence of sufficiently qualified participants, we decided to choose a ready-made option and choose the HighROV board. We chose her because she has all the necessary connectors for our payload.

To keep costs down, the boards were bought unassembled and we had to assemble them to use them. Wiring was carried out using solder paste and a special apparatus. We applied thermal paste to the pads, after which we arranged the elements and warmed up the board in a special apparatus.

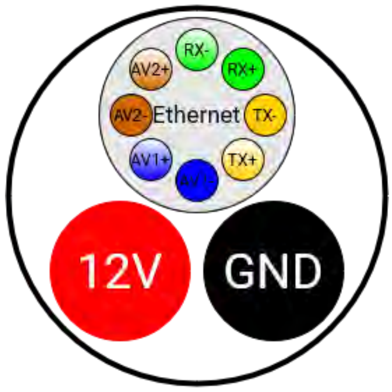
Picture 18 - Enclosure for electronics

Tether

Picture 19 - Tether folded

Picture 20 - Tether connector, control panel side.

We use a twenty-meter long tether to power and control the robot. This length of cable allows ROV to reach any part of the pool. Based on the data on the size of the pool obtained from MATE, we calculated the required cable length according to the Pythagorean theorem:
L= √((4m)^2+(10m)^2)≈11m
Since the cable is connected to the control panel, which is located at some distance from the pool, we added another 9 meters to the total length of the cable. So we insulated it in a nylon sleeve. Also, in order to prevent the cable from escaping from the enclosure, there is a special mount on our ROV. Based on the experience of previous years, we decided to replace the 12AWG cable with 10AWG one, which allowed us to reduce voltage losses. Our cable consists of two power wires and an Ethernet cable [10], which we use to transmit a digital signal and two analog video signals.



RX, TX - Control signal and telemetry transmission
AV1, AV2 - Analog video signal
12B, GND - Power

Picture 21 - Tether diagram

Tether management protocol

When performing tasks in the pool, the cable is controlled by the cable manager. To ensure that the cable was not damaged

during the mission, transportation, storage and connection, a cable management protocol was created for the cable manager and the rest of the team members. The cable management protocol is in the appendix.

Software

Software is needed to control the vehicle, and since we use electronics from the HighROV kit, we also use software designed specifically for it. This is the software we have only slightly modified for the payload used this year. The software consists of 2 parts: upper and lower. They are described below. In addition to the main software, we use regulators and other programs to control the ROV. Regulators are needed to simplify the control of the vehicle. There are other programs: programs for automatically swimming along the lines and docking with the station, a program for calculating the location of a buoy, programs for measuring the size of underwater objects and a photo mosaic program. All these programs are executed on the control panel, while not interfering with the pilot's control, as the image from the ROV goes to an external monitor.

Safety rationale

It is important that team members adhere to safety measures. They are required to ensure that people do not injure themselves during the construction and use of the ROV.

Personnel safety

During training, working with dangerous tools, our mentors told us safety rules so that we would not injure ourselves. For example, when cutting lead for ballasting, people wore goggles and gloves. And during the use of the soldering iron, ventilation was turned on. We also worked under the constant supervision of mentors so that they could help in difficult times and everything went as safely as possible.

Equipment safety

Picture 22 - Protective nets for propulsion

Picture 23 - 25A fuse installed on the power cable

We have designed the machine to be safe. These are the security measures we used:

- Grids on all thrusters. They are needed so that the thrusters do not injure someone during use.
- The electronics unit is completely tightly sealed, since there is a risk of water intrusion, which can cause a short circuit, due to which a person may be electrocuted.

- There are no sharp corners on the machine that could cause scratches.
- Warning stickers on potentially hazardous areas.
- A 25A fuse that blows immediately in the event of a short circuit, which causes the machine to turn off power.

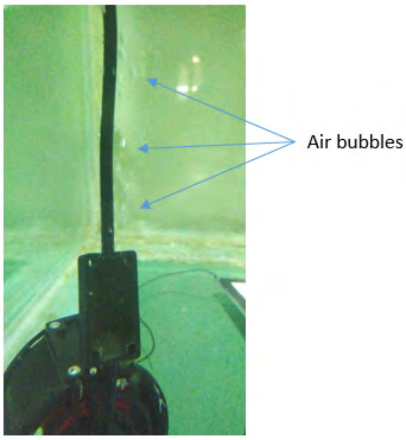
Operational safety

Also, during use, we do not pull the cable, so as not to damage it and there are no problems with a short circuit in the pool. Also, employees do not try to put anything into the thrusters, so as not to accidentally get hurt. The staff also handled the ROV with care so as not to accidentally drop it on anyone. We also have security checklists in the appendix.

Critical analysis

Method of testing devices

Our team, creating the ROV, set the main goal - to make the ROV workable. To do this, it was necessary to use only working components.



Picture 24 - BLDC driver leakage detected with compressed air

One of the conditions under which a component is considered working is watertightness. We have sealed all the components, because water can leak into them, which leads to their failure. To check for watertightness, we used a compressor, pressurized the container and looked to see if bubbles were coming out if we put it in the pool. Also, another way to check for tightness is to immerse the component in the water in the pressure chamber. It is easy to adjust the pressure in it, which makes it easier to check for tightness. The only disadvantage of this method is the small volume of the pressure chamber.

The electrical components had to be checked for operability. Before starting the electrical components, it is necessary to check them with an electrical tester. In addition, load testing of the tether was carried out to determine voltage losses.

Troubleshooting strategies and methods

In the process of development, testing and operation, we were constantly faced with problems, so we needed to develop an effective strategy and tactics for eliminating them for ourselves. As an example, we used the experience of our mentors, who are able to fix problems very quickly and efficiently.

1. The first step in the strategy is to isolate the problem. It is necessary to determine exactly where the failure occurred, find and isolate the problematic system or subsystem, if possible.
2. The second stage. If the cause of the problem is not obvious now, we assume that the failure was due to the software problem. If it's not the software, then we assume that the problem is electronics, and we conduct a comprehensive check of the boards and connectors.

Our team encountered many problems that needed to be fixed. To do this, we have identified the main troubleshooting methods:

1) Restoration repair after damage. We used this method when it was necessary to repair the damaged thread of the penetrator or when it was necessary to solder the disconnected fallen wires inside the camera compartments blocks.

2) Modular replacement after failure of a complex node. An example to this is the replacement of a faulty depth sensor module with a serviceable model.

Prototyping and Debugging

Prior to the manufacture of the ROV, we had to decide on its concept. Each member of our team had their own thoughts on the creation of the ROV. Therefore, everyone created a model of the ROV from improvised means. The main task was to show what the ROV would look like, how the thrusters and payload would be placed. During the discussion of experimental samples, our team came up with the idea of an ROV that we used in the competition itself.

Picture 25 - Frame concept

In addition to ROV, we started prototyping the profiling float. To debug the float buoyancy engine, we first controlled it from the surface via a cable. When creating prototypes, our buoy had different mechanisms and sizes, but we decided on a design that could be freely dragged with the help of the manipulator, and also that there was not too much air inside the buoy, because that would interfere with the tasks.

Picture 26 - Buoy model

Accounting

Budget

The team's budget was chosen at the very first meetings. To create it, we analyzed the work of other teams, used our past knowledge and considered the fact that we already had some components and did not need to buy them. Based on this, we estimated the approximate cost of what we need. This helped our team budget.

At the time of the creation of the team, it was not known what the tasks for the events in 2022 would be. Therefore, we assume a preliminary budget plan, which was drawn up on the basis of the allocation of fixed assets. For example: When we received the full rules of procedure for the trial, we found that we followed everything that we had planned before.

Estimated approximate expenses, we came to the conclusion that we ourselves will be able to compensate for our expenses if each participant invests in a sum of money each month, exactly 70 dollars. In total, for the whole year, our budget from participants' contributions amounted to 5 715 dollars. The main costs for the collection of ROV collected 1 450 dollars, and operating expenses 3 850 dollars. The rest of the company is 430 dollars.

The planned budget was made to avoid cost overruns. All purchases were made with estimates that cover purchases to be within budget. In order to control the budget, we kept a cost table that you can see in the application. If upon purchase of a new component and writing it into the table we saw that we were going over the budget, we started to make more economical purchases.

Travel and travel expenses

Regional competitions

For training, we had to come to the pool, which was located in the MSU Nevelskoy. We usually drove in the cars of our mentors and parents, so we did not spend money on buying a taxi or on public transport.

Since the regional competitions were held in our city, we did not need to buy tickets for the trip.

World competitions

Since the world competitions will be held in a remote format, we don't need to spend money for the trip.

Appreciations

This year, many people and companies have supported us by donating money, materials, time and experience. First of all, we want to thank our mentors, Vadim Sorin and Aleksandr Omelyanenko. They helped to develop technical skills, without which it would not have been possible to create a workable ROV. We also want to thank The Center for Robotics Development for investing in our team and providing space for the development of the vehicle. We want to thank the Maritime State University for providing a place for training. And we want to thank the parents of our team members for their help in transporting the team members, props, ROV and all devices for its normal functioning.

Links

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Appendix

Tether management protocol

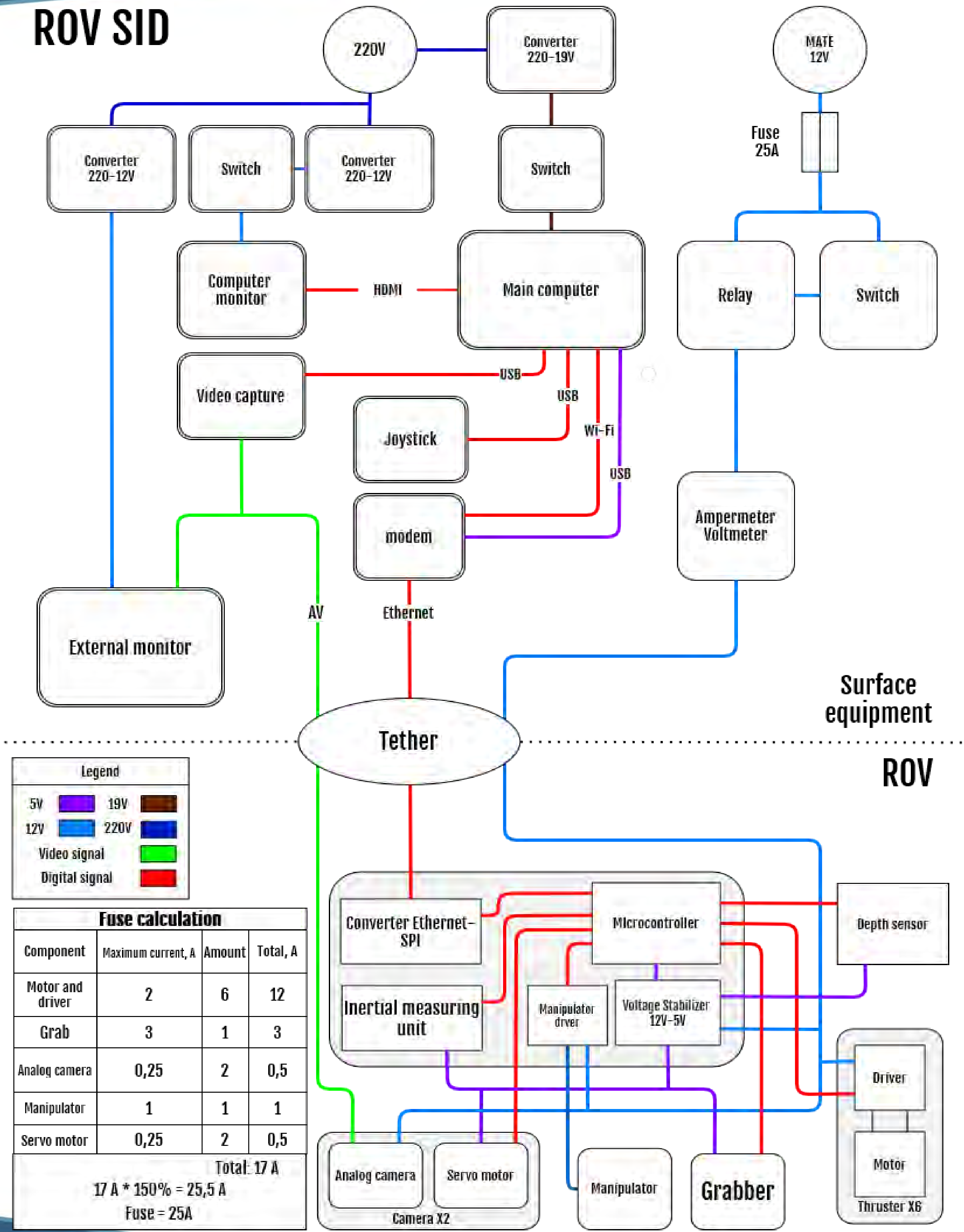
Point	For what	How is it performed
Mission control:		
Avoid sagging	The tether should not pull the ROV down to the bottom	We pull the tether out of the water to the length we need
Avoid stretching	The tether should not pull the ROV to the surface and prevent it from moving	Feed the tether into the water as the ROV moves away
Don't Cling to props	The cable must not move the props, and must not interfere with the ROV's movement.	Move the cable so that it does not interfere with props and ROV's movement
Avoid cable twisting	Twisting the cable can damage it.	Do not turn the ROV only in one direction
Avoid stepping on the cable	The cable may be damaged if stepped on.	Minimize movement near the cable and watch your feet
Transportation:		
Do not pinch the cable	The cable may be damaged when pinched.	Moving the cable on the machine in a horizontal position
Avoid stepping on the cable	The cable may be damaged if stepped on.	Minimize movement near the cable and watch your feet
Storage:		
Figure eight styling	When folded in this way, the cable takes up the least amount of space.	After using ROV, the cable is folded according to this scheme
Do not allow water to enter the connector	If water enters the connector, it may be damaged.	Keep cable out of water
Avoid cable twisting	Twisting the cable can damage it.	When assembling the cable, check it for twists and correct them.
Connection:		
Attaching the cable to the remote control and the machine	With sharp dash of the cable, the connector and the main penetrator may be damaged	The use of carabiners and special mounts on the remote control and ROV for cable attachment
Check the connector for water.	When the contacts of the connector are closed with water, the ROV may break	Before each connection, check the connector and drain it if water gets in.

Table 5 - Cable management

Budget

Team name		The Center for Robotics Development	From:	29.09.21
Mentor		Vadim Sorin	To:	06.05.22
Source				Total amount
Expenses				
Category	**Type**	**Descriptions / Examples**	**Project cost, $**	**Budgeted value, $**
Sensors	Reused	Depth sensor, navigation and flight sensor, 2 cameras	321.43	0,00
Electronics	Buy	Electronics unit, payload materials, cable	892.9	892.9
Electronics	Reused	MUR Thruster 1500 thrusters	1607.15	0,00
Electronics	Reused	Monitor, remote	714.3	0,00
Hardware	Buy	Costs for layouts, sealant	1071.43	1071.43
Hardware	Reused	Camera body, enclosure, electronics housing kit	571.43	0,00
General	Buy	Registration, salary for mentors	4821.43	4821.43
Travel	Buy	Pool workout	267.9	267.9
			Total income:	0.00
			Total expenses:	10267.9
			Total expenses-Re-used/Donations	7053.6
			Total Requested:	(7053.6)

ROV SID



Fuse calculation

Component	Maximum current, A	Amount	Total, A
Motor and driver	2	6	12
Grab	3	1	3
Analog camera	0,25	2	0,5
Manipulator	1	1	1
Servo motor	0,25	2	0,5
			Total: 17 A

17 A * 150% = 25,5 A

Fuse = 25A

Safety Check-lists

Safety Checklist for ROV development	**Safety Checklist for ROV exploitation**
Security measures of the company's employees during the design and manufacture of ROV	Safety measures of the company's employees when the ROV is first connected to the power supply on land
A) When working on the machine	1. Check the design of the ROV for the integrity and correctness of the assembly and check the drawings
1. When working on the machine, persons with experience and knowledge of working on this machine are allowed	2. Check the electronics on the ROV and make sure that it is connected correctly
2. When working on the machine, an employee of the company must have gloves, protective glasses and special protective clothing	3. Supply power to the ROV through the remote control unit, while making sure that there is no danger of electric shock to the company's employees
3. Upon completion of work on the machine, it is necessary to restore order in the workplace	4. In case of problems, identify a problem when the ROV's power is turned off
B) In the production of components and mechanisms on the ROV	Safety measures of the company's employees during the first ROV connections in the water
1. All manufactured parts must be stored strictly in a certain place	A) Before starting to connect the power supply to the ROV
2. Parts with roughness must be protected with special tools	1. Check the integrity of the ROV construction
3. The manufactured mechanisms must be maintained in optimal condition, lubricated and checked for operability	2. Check the sealing of all components and units of the ROV
C) When assembling the ROV for the company's employees	3. Check the buoyancy of the ROV and its balancing in the water environment
1. The ROV must be assembled by several employees of the company	4. Apply power to the ROV, making sure that none of the company's employees has contact with the water in which the vehicle is located
2. The assembly of the ROV must be carried out under strict compliance with the drawings and prototyped models	5. Check the ROV for operability, in case of a malfunction of the vehicle, it is necessary to turn off the power and bring it to the surface for its diagnosis
If an employee of the company receives an electric shock	Safety measures when connecting the ROV in water
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	1. Check the sealing of the ROV wire connections
2. It is necessary to check the breathing and pulse of an employee of the company	2. Check the ROV construction for integrity
3. It is necessary to report this incident to the mentor and call a doctor if necessary	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
If an employee of the company receives a physical injury	4. Check the performance of the ROV in the water, setting in motion each of its mechanisms in turn
1. It is necessary to provide a safe area around the injured employee	If an employee of the company drowns
2. It is necessary to provide first aid to the injured employee	1. Quickly get the injured person out of the water
3. It is necessary to report this incident to the mentor and call a doctor if necessary	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

Таблица. 8 Чек-лист безопасности

Table 9 - Task execution plan

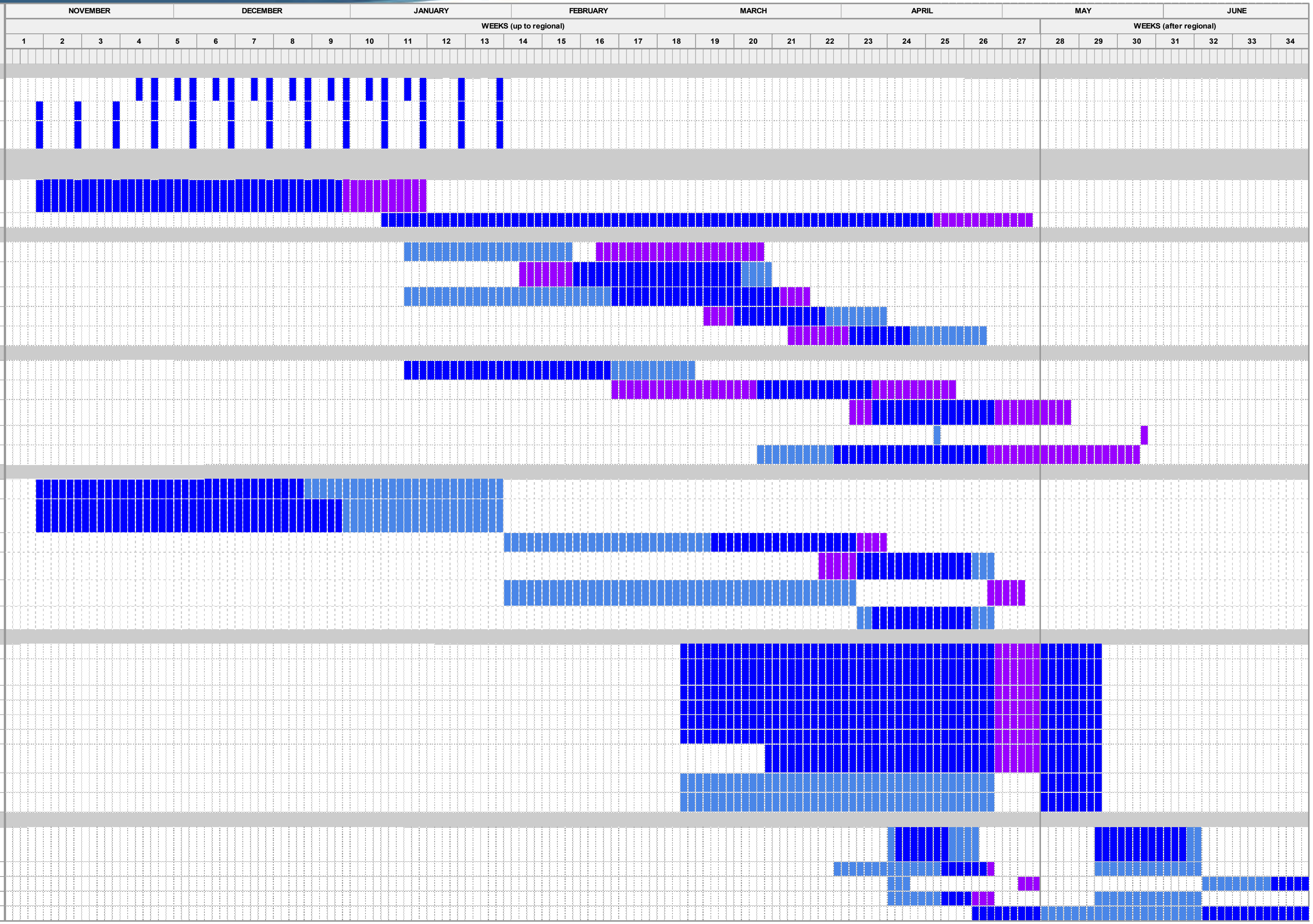
Dive Number	Plan	Points
0	Finding mort on video using AI	10
	Showing the float built prior to the competition	5
	We take the buoyancy module into the manipulator, hydrophone into the grabber and the cable into the rear hooks.	
1	Moving to the place of the hydrophone	
	Placing the hydrophone	5
	Moving to the old buoyancy module	
	Turning and removing the old buoyancy module with a gripper	10
	Installing a new buoyancy module from the manipulator	10
	Inspecting the cable	5
	Cutting cable with rear mesh	10
	Removing a damaged cable with a hook	5
	Installing a new cable from the rear hooks	10
	Fixing a new cable with a manipulator	10
	Moving to the ghost net	
	Releasing the ghost net with the back mesh	10
	Floating up	
	Swimming to the side of the pool pushing the ghost net with a hook	5
	Dive summary:	95
On the side of the pool	Taking a patch into the hook	
2	Moving to the beginning of the rope on the net	
	Inspecting net autonomously	25
	Counting damaged areas	5
	Installing the patch	10
	Removing algal marine growth with a hook	5
	Removing encrusting marine growth with a manipulator	5
	Moving to the mort	
	Taking mort into the manipulator	5
	Determining the average size of the fish cohort	15

Dive Number	Plan	Points
2	Determining the biomass of the fish cohort	5
	Moving to the collection tube	
	Inserting mort into the collection tube	5
	Floating up	
	Dive Summary:	80
On the side of the pool	Taking the float into the manipulator	
3	Moving to the launch site of the float	
	Launching the float. The float makes two profiles using a buoyancy engine	30
	Moving to the beginning of the search area	
	Flying a transect line	10
	Mapping the wreck	5
	Moving to the shipwreck, along the way collecting photos for photomosaic	
	Measuring the length of the wreck	10
	Completing the collection of photos for photomosaic	5
	Making a photomosaic using software	20
	Moving to the place of the hydrophone	
	Picking up the hydrophone with a grabber	5
	Moving to the old float	
	Determining the location where the float will next surface	5
	Picking up the old float with a manipulator	10
	Moving to the hole in the ice	
	Floating up in the hole	
	Taking the hydrophone and float	
	Moving to the docking station	
	Autonomous docking to the docking station	15
	Dive summary:	115
	Total:	290

Table 7 - Project costing

Project Costing						Reporting Period:	
Team Name:				The Center For Robotics Development		From:	29.09.21
Mentor:				Vadim Sorin		To:	06.05.22
Date	Type	Category	Expense	Description	Sources/Notes	Amount, $	Running Balance
14.01.22	Purchased	Hardware	Sealant	Two-component sealant of HighROV	Used to seal penetrators	(30,00)	(30,00)
18.02.22	Purchased	Electronics	Onboard electronics	Board of HighROV, electronic components	Used for control system. Assembly was carried out independently to reduce the cost	(285,00)	(315,00)
18.02.22	Purchased	Hardware	Gripper	MUR Arm Gripper, accessories	Used to complete tasks. Assembly was carried out independently to reduce the cost	(155,00)	(470,00)
18.02.22	Purchased	Hardware	Layout costs	Pipes, scotch, velcro fasteners	Used for training	(145,00)	(615,00)
25.02.22	Purchased	Electronics/Sensors	Buoy material	Motor, hall sensors, Arduino Nano, batteries, buttons	Used to assembly buoy	(70,00)	(685,00)
11.03.22	Purchased	Hardware	Payload	Materials for the assembly of grip, hook, back mesh	Used to complete tasks	(145,00)	(830,00)
19.03.22	Purchased	Electronics	Tether	Power wires, Ethernet, braid	Used to power and communicate with equipment	(285,00)	(1 115,00)
19.03.22	Purchased	Electronics	Connector	Connector and mating part	Used for cable assembly	(55,00)	(1 170,00)
01.04.22	Purchased	General	Registration	Registration payment for international competitions	Price for the whole team	(200,00)	(1 370,00)
08.04.22	Purchased	Hardware	Frame material and manufacturing	Material and payment for production	Used for ROV frame	(215,00)	(1 585,00)
22.04.22	Purchased	Hardware	Material and manufacture of buoyancy modules	Material and payment for production	Used for buoyancy system	(70,00)	(1 655,00)
	Purchased	Hardware	Bracing	Screws, nuts, ties, electrical tape	Purchased throughout the development of the ROV for various needs	(20,00)	(1 675,00)
	Purchased	General	Salaries for mentors	Payment for the work of mentors working with our team	Payment for consulting hours (Classes) and the price of one hour	(3 430,00)	(5 105,00)
	Purchased	Travel	Pool payment	MSU fee for conducting training	~15 dollar/training	(115,00)	(5 220,00)
	Purchased	Travel	Expenses for training	Taxi rides to training venues	Used to move people and equipment to the training site	(65,00)	(5 285,00)
14.01.22	Re-used	Electronics	Control box	Intel NUC, SSD, other electronics	From the resources of Robocenter team	(5 000,00)	(5 285,00)
14.01.22	Re-used	Electronics	Monitor	SUPRA STV-LC19820WL	From the resources of Robocenter team	(65,00)	(5 285,00)
21.01.22	Re-used	Electronics	Thrusters	MUR Thruster 1500	From the resources of Robocenter team	(1 285,00)	(5 285,00)
21.01.22	Re-used	Sensors	2 Cameras	Foxeer Razer Nano	From the resources of Robocenter team	(140,00)	(5 285,00)
21.01.22	Re-used	Sensors	Sensors	Depth sensor, IMU	From the resources of Robocenter team	(115,00)	(5 285,00)
21.01.22	Re-used	Hardware	Corps	Sealed transparent camera housings	From the resources of Robocenter team	(170,00)	(5 285,00)
21.01.22	Re-used	Hardware	Electronics Enclosure Kit	Sealed enclosure and set of penetrators	From the resources of Robocenter team	(285,00)	(5 285,00)
	Cash donated	General	Member contributions	Payment for participation in the team	Monthly membership fee	5 715,00	430,00
						Total raised:	5 715,00
						Total spent:	(5 285,00)
						Final balance:	430,00

№	NAME OF THE TASK	RESPONSIBLE	Start Date	Finish Date	DURATION
1	**Mastering New Skills**				
1.1	Constructor training	Mechanical engineers	20.10.2021	12.01.22	82
1.2	Electronics engineers training	Electronics engineers	08.10.2021	25.01.22	107
1.3	Training Software engineers	Software engineers	08.10.2021	28.02.22	140
2	**Review of the topic and objectives of the competition**				
2.1	Identification of the theme of the competition	All	08.10.2021	21.01.22	103
2.2	Creating layouts	All	14.01.22	11.04.22	87
3	**Creation of the apparatus**				
3.1	Development of the ROV project	All	12.01.22	18.02.22	36
3.2	Creation of control Electronics engineers	Electronics engineers	18.02.22	18.03.22	30
3.3	Creating a Payload	Mechanical engineers	12.01.22	25.04.22	103
3.4	Creation of Rama	Mechanical engineers	12.01.22	25.04.22	103
3.5	Sealing	Mechanical engineers	12.01.22	25.04.22	103
4	**Create a buoy**				
4.1	Create a Buoy Drawing	Mechanical engineers	12.01.22	25.04.22	103
4.2	Parts manufacturing	Mechanical engineers	15.01.22	25.04.22	100
4.3	Assembly of the buoy mechanism	Mechanical engineers	15.01.22	25.04.22	100
4.4	Check for sealing	Mechanical engineers	25.04.22	25.04.22	0
4.5	Building Electronics engineers Buoy	Electronics engineers engineers	16.02.22	25.04.22	69
5	**Software writing**				
5.1	Creating Virtual Scenes	Software engineers	08.10.21	28.02.22	140
5.2	Checking the solution of problems vertically	Software engineers	08.10.21	28.02.22	140
5.3	Writing code for the machine	Software engineers	16.02.22	25.04.22	69
5.3.1	Writing Mate Remote Cod	Software engineers	18.02.22	25.04.22	67
5.3.2	Writing AI to identify morta	Software engineers	16.02.22	25.04.22	69
5.4	Code writing for a buoy	Software engineers	25.04.22	30.04.22	5
6	**Writing Tech. Documentation**				
6.1	Writing Tech. Report	All	03.03.22	25.04.22	52
6.2	Writing corporate responsibility	Igor Murzin	03.03.22	25.04.22	52
6.3	Writing a spec sheet	Mariia Abramova	03.03.22	25.04.22	52
6.4	Writting JSA	Игорь Бондаренко	03.03.22	25.04.22	52
6.5	Creation Poster		03.03.22	25.04.22	52
6.5.1	Poster filling	Svyatoslav Chalyy	03.03.22	25.04.22	52
6.5.2	Graphic Creation of a Poster	Вячеслав Кукунин	01.04.22	25.04.22	24
6.6	Creation of ROV scheme SID	Александр Католик	03.03.22	25.04.22	52
6.7	Creation of VR Assets	Timur Mangliev	03.03.22	25.04.22	52
7	**Testing**				
7.1	Testing the Machine for Operability	All	25.04.22	05.05.22	10
7.2	**Sealing test**	All	14.04.22	29.04.22	15
7.3	**Buoyancy Testing**	All	26.04.22	28.04.22	2
7.4	**Electrical Circuit Testi**	All	27.04.22	07.05.22	10
7.5	**Training**	All	**29.04.22**	**05.05.22**	**10**



Color			
Meaning	Planned	Intersection of planned and completed	Accomplished