MARITIME STATE UNIVERSITY

ROBOTICS TEAM

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INFORMATION TECHNOLOGY SOLUTIONS

The team was created in 2014 and since then has been successfully working on the development and creation of ROV designed for a wide range of tasks in the field of world ocean development. The team members are students of different specialties in electronics, physics, and programming. We adhere to the thesis that well-organized and planned joint work in one team of people from different professional areas allows to achieve maximum efficiency of work in the process of creating ROV due to the competent division of responsibilities between the participants according to the technical skills and specialization of each.

Maritime State University
Named after G.I. Nevelskoy

Оглавление

I. ABSTRACT

Integrated and operational ecological monitoring of the world's oceans is currently a particular challenge due to the increasing impact of various anthropogenic factors on maritime ecosystems. According to a 2018 report published in Current Biology, only 13% of marine ecosystems remain intact, while the rest are affected by human activities. All of this ultimately leads to fatal consequences for marine wildlife. Overfishing activities, rising sea levels due to climate change, and pollution by plastics and various types of petroleum products have reached global proportions. In this regard, a comprehensive integrated approach is needed to prevent irreparable detrimental effects on the ecology of the world's oceans. One of the possible solutions is to use underwater specialized hardware-software robotic complexes that enable systematic ecological monitoring, study of assimilative capacity of the marine ecosystems and efficient liquidation of different types of pollutants. Our team has extensive experience in designing underwater robots to solve actual problems in the field of marine robotics. The accumulated experience made it possible to design and create a Remotely Operated Unmanned Underwater Vehicle (ROV), which is oriented towards the fulfillment of tasks in the field of marine ecology set by the competition organisers. The ROV is equipped with two analog video cameras, a manipulator, a computer vision system, and a mini-ROV with an automatic retracting device. Our team has worked a hard and long process from the development concept to the final realization of the ROV. The stages of development and creation are presented in this technical report. This document includes everything about the ROV creation process: the design stage, building the various payload elements and electronic components, creating the software, debugging the assembled ROV, and troubleshooting

II. INTRODUCTION

Our team is from the Maritime State University of Admiral G.I. Nevelskoy. The team was formed in 2014 and since then has been successfully working in the development and creation of ROV for a wide variety of tasks in the global ocean area. The team members are students of different specialties in electronics, physics, and programming. Well organized and planned teamwork of people from different professional areas allows to get the maximum efficiency in the process of creating devices due to the competent division of responsibilities between the participants according to the technical skills and specialization of each person. The mission of our team is to create efficient and reliable solutions for the vast marine and underwater industry, and to develop students' creativity and research initiatives to form a highly skilled scientific and technical workforce in the field of underwater robotics.

III. WORK ORGANIZATION

There is a clear division in our team into the following roles: designer, programmer of upper and lower level, electronics engineer. The student takes a role depending on the competencies he has. Students are guided by mentors who control the process of building the ROV, give advice on any questions that a student may have, and take part in the coordination of the entire project.

Team meetings are conducted each week in a specially equipped robotics lab, at which time each team member shares their progress from the previous week, discusses future tasks and missions, and assigns tasks for the next week.

The management and planning of the work process is done through team meetings and face-to-face meetings between team members and mentors, as well as online in a shared social networking conference. The documents and materials required for teamwork are shared with each team member.

An important characteristic of our team is that the mentors who support members in the process of apparatus development were members of the team members themself in the past, thanks to which they have not only the required technical knowledge, but also invaluable experience of working on ROV creation, understanding the structure and essence of teamwork in the project, which is certainly very important for training and educating new members.

Our team focuses on the issue of compliance with all the required safety requirements in the process of organizing the work process. In the current preparatory cycle, in addition to strict compliance

with safety requirements for soldering equipment, power tools, CNC machines and 3D printers, additional measures were taken due to the spread of the epidemic of coronavirus infection. These measures consisted in constant monitoring of the well-being of all team members, measuring body temperature before starting work, observing social distance and wearing personal respiratory protection.

Table1.

THE UBIQUITOUS PROBLEM OF PLASTIC POLLUTION		**THE CATASTROPHIC IMPACT OF CLIMATE CHANGE ON CORAL REEFS**		**MAINTAINING HEALTHY WATERWAYS II: DELAWARE RIVER AND BAY**	
Seabin – “Cleaning up our ocean one marina at a time”	Manipulator	Flying a transect line over a coral reef and mapping points of interest	The motor system. Video system. Depth sensor. Software for stabilization at depth.	Retrieving a sediment sample from inside a drain pipe to analyze for contaminants	Mini-ROV. The Mini-ROV video system. The hook. A system for adjusting the length of the Mini-ROV cable.
Remediation: Removing plastic pollution from top to bottom	Trash collection basket	Using image recognition to determine the health of a coral colony by comparing its current condition to past data	Software for recognizing shapes and colors	Estimating the number of mussels in a mussel bed	Manipulator. Video system. Software for object recognition.
		Propagating corals onto the reef	Manipulator	Eel restoration	Manipulator
		Culling an outbreak of Crown of Thorn sea stars	Manipulator	Creating a photomosaic of a subway car submerged to create an artificial reef	The motor system. Video system. Software for "stitching"

					images into photomosaic.
		Collecting samples of sponge species for pharmaceutical research	Manipulator		

IV. Frame & Buoyancy

When designed the frame, the focus was on its mass and size characteristics, simplicity in service and lightness of construction. Based on these factors, a frame support structure was designed in SolidWorks computer-aided design software (figure ...).

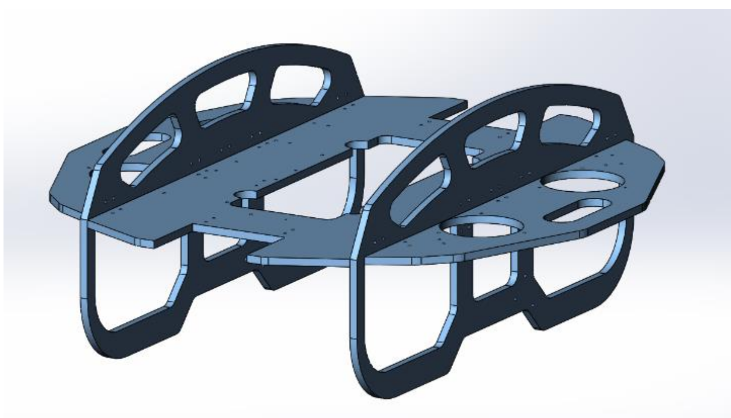


Fig 1. The layout of the ROV thruster complex

The designed form of the frame allows for rational placement of all ROV elements and components, as well as for easy access to all the components in ROV it is required for repair works or replacement of the components. The ROV frame consists of the main flat horizontal plate with the size of 620x620 mm with cut holes for fixing the payload and two supporting flat plates with the size of 258x548 mm. The frame was designed with the following requirements in mind:

- missions to be performed by the ROV;
- the payload;
- the number of thrusters and their location scheme.

Additional structural rigidity is provided by a horizontal support made on a 3D printer, which also serves as a fixing element for the manipulator.

The location of the payload modules was organized in such a way as to ensure minimal displacement of the center of gravity of the fully assembled ROV relative to the center of gravity of the assembled frame. This design further simplified the process of balancing the ROV during in-water tests. The form of the horizontal platform, as well as the design of the sealed bulb, allow, if necessary, relatively easy integration of additional payload modules on this ROV.

System for collecting plastic waste from the surface of marine areas
To carry out the task of collecting plastic debris from the sea surface using the 3D printing method, a quick-detachable flask with a check valve was made. It was made with perforations to minimize the impact on the overall buoyancy of the ROV in the event of its mounting / dismounting. Since the plastic debris is on the surface, the collection system is mounted in such a way that when the device ascends, it is at the water-air interface. As soon as the ball enters the container with the flow of water, the valve does not allow it to float out, thereby providing a quick and reliable way to eliminate contamination.

To minimize the weight and size characteristics of the ROV, polypropylene sheet with a density of about 980 kg/m3 was used as the material of the load-bearing frame. Initially it was supposed to use sheets of 10 mm thickness. But to reduce the total weight of the finished complex, we decided to conduct a computer simulation of the load distribution in the case of using the original material with a thickness

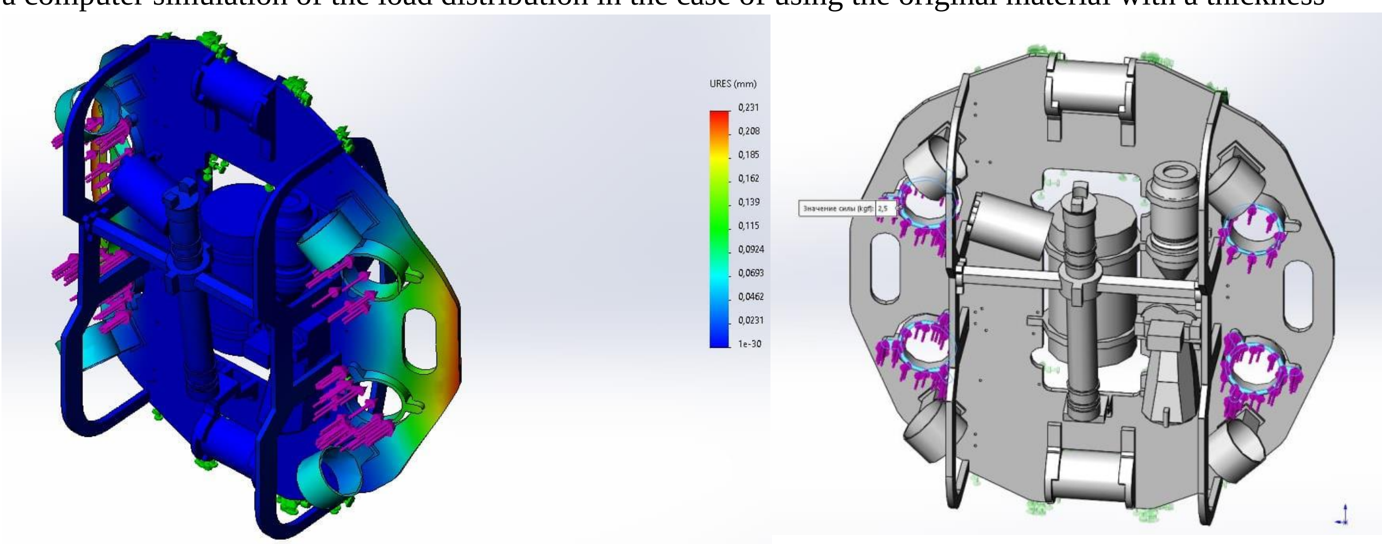


Fig 2. The layout of the ROV thruster complex

of 8 mm. The result of the simulation is shown in the figure 2 According to the obtained distribution, using 8 mm thick polypropylene as a frame material will not lead to deformation of the carrier plate and significant reduction in the strength characteristics of the finished enclosure.

Material	Density, kg/m^3	Water absorption, %	Compressive strength, MPa	Special features
Styrofoam	15 – 25	2	0.05-0.2	Pluses: Low cost, low density Minuses: brittle, high water absorption coefficient
PS-1-350 polystyrene foam	300-400	<0.5	6.9	Pluses: high strength characteristics, the most suitable material for machining
extruded polystyrene foam;	30- 40	≤0.2	0.25-0.5	os: low cost, low water absorption coefficient Cons: poor wear resistance, flammability, sensitive to UV light
polyurethane foam	40-80	≤0,1	0.31	Pros: elasticity, durability, nonflammable Cons: Relatively high cost

Table2.

The frame was made by CNC milling, thus achieving high precision of the overall dimensions of the finished body parts. During the milling work, all necessary safety measures were observed, such as the use of appropriate personal protective equipment, milling only on correctly working equipment with the use of serviceable tools, etc.

The following materials were originally considered for making the buoyancy of the apparatus:

- Styrofoam;
- PS-1-350 polystyrene foam;
- extruded polystyrene foam;
- polyurethane foam

Initially it was decided to make the buoyancy of the submersible from polystyrene foam PS-1-350 due to its high strength characteristics, low water absorption coefficient and the possibility of relatively simple subsequent mechanical processing to give the desired shape of the final product. But as a result, we were faced with the difficulty of buying this material, which lay in the absence of offers on the market for selling small amounts of PS-1-350 (the minimum volume of the purchase party was 1 m3). In this regard, the final choice fell on the purchase of extruded polystyrene foam because of its best value for The chosen layout of the thruster ensures controllability of the vehicle by six coordinates - move, lag, depth, course, roll and pitch (figure ...).money and the required characteristics.

Fig 3.

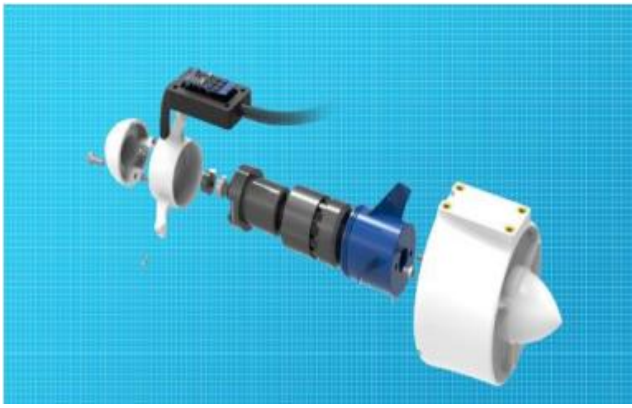
The analysis of the assembly of the apparatus with a payload showed the need to make the buoyancy of the total volume of about 1202*10-6 m3. As a result, this volume was distributed among 4 separate elements, which were installed on the horizontal carrier plate.

V. THRUSTERS

Our ROV is equipped with 8 brushless thrusters: 4 vertical and 4 horizontal, placed according to the vector scheme at the angle of 45 degrees. This configuration ensures high maneuverability of the vehicle and stability of its angular position on roll and pitch, which is one of the key reasons for successful performance of respective missions. The thrusters are an assembly consisting of the following elements:

- Three-phase, brushless motors placed in a hermetically sealed, streamlined enclosure;
- Three-phase motor drivers;
- Hull-screw system.

The basic characteristics of the used thrusters are given in the table 2



Parameters	Values
Kv	350
thrust	2 kg
Working voltage	12-24V
MAX. current draw	10A
ESC	30A
MAX. Turnover	5600rpm.

Fig 4.

The chosen layout of the thruster ensures controllability of the vehicle by six coordinates - move, lag, depth, course, roll and pitch (figure ...).

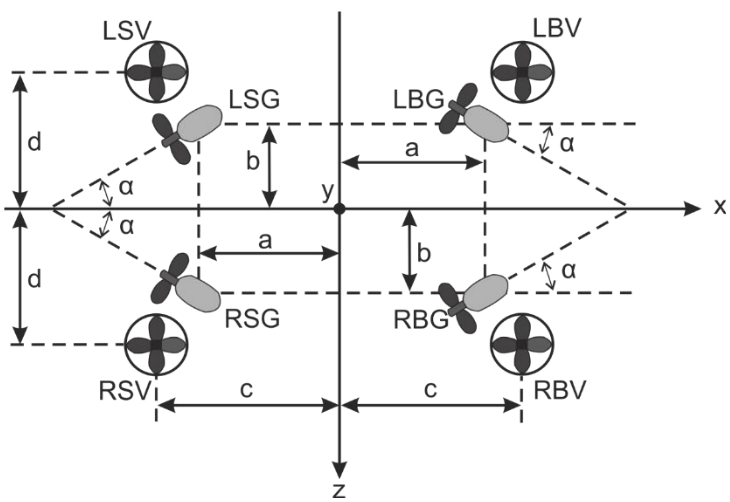


Fig.5. The layout of the ROV thruster complex

The connection between the control actions and the thruster corresponds to the following expressions:

$$F_x = (F_{LSG} + F_{RSG} + F_{LBG} + F_{RBG}) \cdot cos\alpha$$

$$F_y = F_{LSV} + F_{RSV} + F_{LBV} + F_{RBV}$$

$$F_z = (F_{RS} - F_{LS}) \cdot sin\alpha + (F_{LB} - F_{RB}) \cdot sin\alpha$$

$$M_x = (F_{LBV} + F_{LSV}) \cdot d - (F_{RBV} + F_{RSV}) \cdot d$$

$M_y = (F_{RSG} - F_{LSG}) \cdot L_\varphi + (F_{RBG} - F_{LBG}) \cdot L_\varphi, L_\varphi = \alpha \cdot sin\alpha + b \cdot cos\alpha$

$M_z = (F_{LBV} + F_{RBV}) \cdot c - (F_{LSV} + F_{RSV}) \cdot c$

To maximize propulsion efficiency, the thrusters are placed in hydrodynamic nozzles made of ABS plastic by 3D printing.

To provide safety of ROV operators and diving team and to exclude probability of getting of various debris and elements of sea nets on the rotating propeller vanes, special protective nozzles were made and installed on the propeller guards (figure ...). The nozzle filling area was selected based on the criteria of ensuring the required level of safety and preserving the thrust characteristics of the vehicle.

The developed ROV includes payload parts that expand its functionality to successfully perform the tasks set by this year's competition organizers. The ROV is equipped with 2 video cameras, a manipulator, a surface debris collection system, and a mini-ROV with a retraction device. A more detailed description of the payload is given below.

VI. MANIPULATOR

To complete tasks of moving objects underwater, the ROV was equipped with a manipulator, the characteristics of which are presented in the table

Name	**Value**
Number of degrees of freedom	2
Angle of rotation of 1st degree (grip rotation)	360^0
Angle of rotation of the 2nd degree (opening of the grip)	From 0 to 120^0
Size of the grip opening	from 0 to 100 mm
Grip force	to 100 H
Manipulator weight in air	1.2 кг
Power supply voltage	24 V
Power required (for operation with two degrees at the same time)	5Вт
Control interface	0/1
Produced	RovBuilder

Table 2. Manipulator characteristics

As experience has shown during testing of the ROV, the location of the manipulator initially selected did not allow to grab some objects. As a result, we chose the position of the manipulator at an angle of 8 degrees relative to the supporting horizontal plate with an offset of 10 cm relative to the front plane of the frame. This combination of camera and manipulator placement gave the best view angle for maximum effectiveness in underwater work. The manipulator is attached to the ROV frame with special holders and supporting brackets. The holders and supporting brackets were made by 3D printing, which made it possible to achieve the required rigidity of the frame and not to increase significantly the total weight of the ROV.

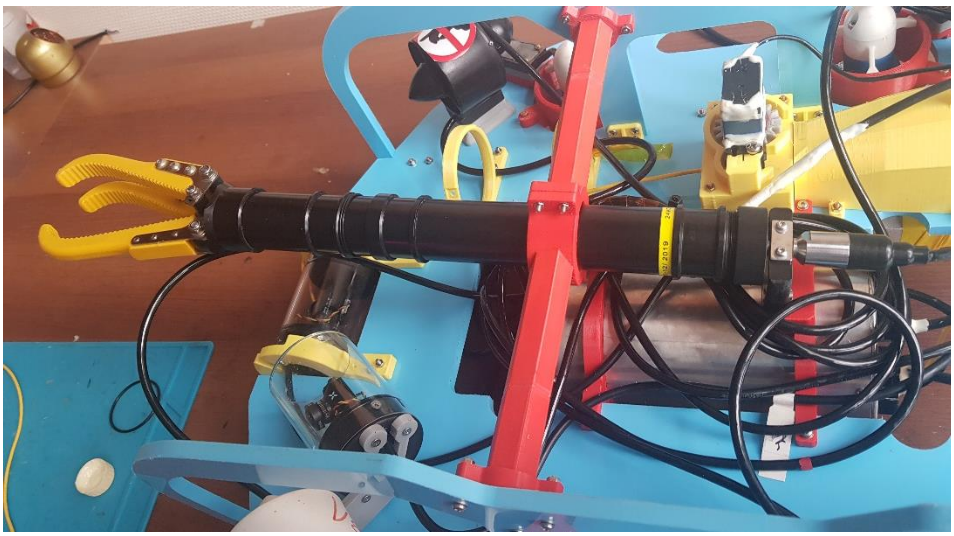


Fig.6. The layout of the ROV thruster complex

VII. ELECTRONICS MODULE

A. Control center

The control system includes a laptop and joystick with five degrees of freedom and a remote control to dispense power, control parameters, and connect multimedia devices. All control is software-based, using a specially developed application to control the robot. The connection between the laptop and the remote control is made via a Wi-Fi router. The monitor is used to display the image from the front camera through the video capture device Rombica Pro Studio.

B. Power supply

Two parallel power connection schemes have been developed to operate under different power conditions. One of the circuits contains an AC to DC converter. The conversion takes place in the range from 110V to 240V, the voltage at the output of the converter:48V.

The 40CPQ060 diode pair is used to avoid collisions between sources if they are connected simultaneously. The power supply to the unit is controlled by a switch. There is also provision for switching off the Wi-Fi router power supply (100-240 VAC to 5 VDC).

To protect the electronic system from abnormal current consumption, a 30A combustible fuse is built into the power cord. All connectors are made on the top side of the case and equipped with protective covers for convenience and to reduce wire bending. In the remote installed voltmeter and ammeter to assess the current input during operation of the ROV. There is also a separate DC/DC converter for its power suppl

C. Hermetically sealed housing

The following solutions were used to ensure the sealing of the electronics unit:

- Cylindrical bulb with dimensions 182x110mm with rubber sealing to ensure tightness of on-board electronic systems
- Epoxy filled penetrators were used for wiring of peripheral devices

D. Electronics Development

Designing the ROV electronics is a complex task and has a set of details that depend on the purpose of the ROV, the operating depth, and the installed payload.

The selection of the right electronic components is the main factor for the stable work of the ROV. Based on our experience with various technical solutions and components, we selected the optimal ROV electronic configuration for this year's tasks.

The electronic part of the ROV consists of 3 subsystems:

Lower level control system consisting of a control controller, a set of sensors and a video system installed inside the unit and protected by a sealed housing

· The second system is the power part, consisting of thrusters, speed controllers and manipulator

· The complex also includes a control panel, located on the ground, which consists of a power supply, current protection, measuring equipment, router to create an access point and connection to the control computer

Below is the steps for selecting electronic components:

1) ground communication protocol

2) communication line

3) adapter, modem and PHY converter

4) control system controller

5) video system

6) physical video communication interface

7) thrusters

8) thrusters control system

9) controlled devices

10) voltage converters

This sequence reduces the chance of collisions between system elements and provides a comprehensive approach to the development of ROV electronics

E. Connecting

To create connection from the device, the Ethernet interface was chosen, which allows you to create a duplex connection with the device and provide a video stream from multiple cameras and has a high noise immunity. To implement the physical layer of the Ethernet interface, a shield based on the chip w5100 is used.

F. Video System

For this year's tasks, the cameras were selected according to the following characteristics:

- Image output interface (digital /analog/AHD)

- Form Factor (boxy / non-boxy)

- Sensor type, light sensitivity

- Focal length (for lens)

- Presence of filters (software, physical)

- Color bit depth (for computer vision)

As a result, we chose a Foxeer 16: 9 1200TVL analog FPV camera (Table).

Resolution	1200 TVL
Matrix	1/2.9 CMOS 16/9 3DNR WDR
Photosensitivity	0.001 LUX
Chipset	Nextchip 2040 DSP
Input voltage	DC 5V ~ 40V
Power consumption current	90 mAh
Viewing angle	~ 160°

Lens	1.8 mm
Signal-to-noise ratio	more 50dB
Operating temperature	-10 - +50 ° C
Dimensions	21.8 x 21.8 mm
Weight	12 g

Table.3. Camera characteristics

Due to the fact that the wired channels for video transmission is only two, (two pairs of LAN-cable) was used switching device - multiplexer, through which you can connect to one channel up to 3 cameras.

To get an optimal field of view during the various missions, it was decided to make the following camera configuration.

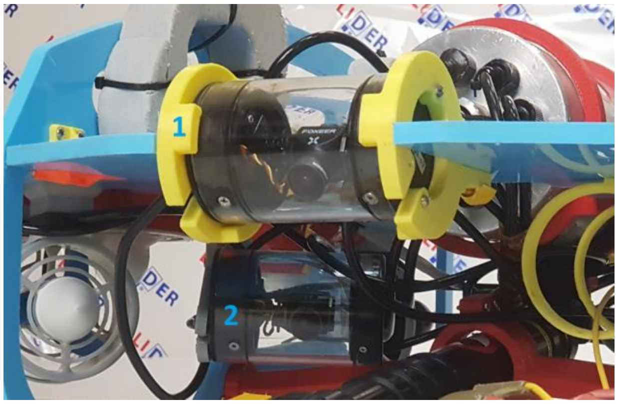


Figure 6. ROV video recording system

The image is displayed on the two monitors of the local control panel. Upper camera 1 is designed for general visual monitoring of the process of performing competitive missions. Lower camera 2 is designed for better perspective when performing tasks connected with precise manipulation of underwater objects (transplanting corals, lifting sea sponges to the surface, setting an eel trap, etc.).

G. Controller

The Arduino Mega 2560 board is used as a control controller, which unpacks data from the control center and outputs control signals to the peripheral devices (ESC, drive drivers) and collects data from the sensors, forming a response package.

H. Expansion Board

To connect the power part and the digital control, an expansion board was designed on which H-bridges, power stabilizers, multiplexer chip and interconnecting lines are installed.

When designing the electronics of the submersible, it is important to consider that the power electronics, the computing modules and the video system are powered from the same current source, and are therefore subject to mutual interference that occurs during operation. To reduce the influence of interference, stabilizers with built-in power filters were used. And for the analog video system, galvanic isolation is provided on the power supply to form a separate "ground", relative to which the video signal will be distributed.

I. Tether

The operating voltage of the ROV is 48 volts. It is supplied to the ROV by a 2.5 mm silicone multicore power tether. This tether is very flexible and highly resistant to weathering.

For connecting network devices we use a cable of the following type

Twisted pair - a symmetrical communication line, providing good interference immunity due to the twisting of insulated conductors together. It can be used for video transmission and communication with the device.

J. Depth Sensor

· For depth measurement and realization of the automatic depth stabilization function the absolute pressure sensor MS5803-30BA was used, which has the following characteristics:

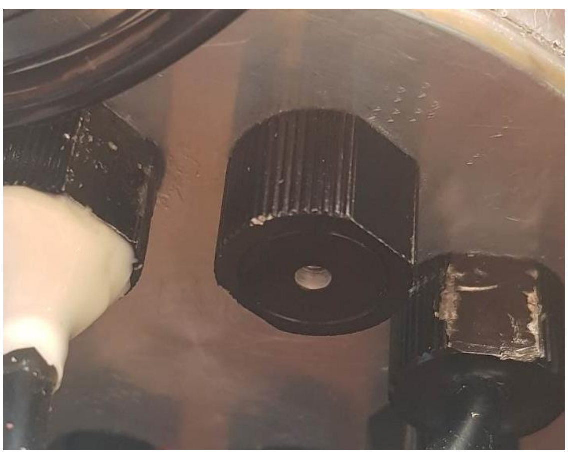


Figure 7. Depth Sensor

· Measuring range: 0 to 30 bar

· Accuracy of measurement: 0.2mbar

Sensor data processing and filtering is also performed on the onboard microcontroller.

For most missions, a depth stabilization feature has been developed that automatically locks the ROV in the operating zone and allows the pilot to avoid being distracted by manual depth stabilization.

VIII. MINI-ROV

To solve the problem of lifting a sample placed in a 6-inch diameter tube to the surface, it was initially planned to purchase a ready-made version of a Mini ROV with the possibility of its integration into the ROV and capable of penetrating inside the pipeline. The analysis of the off-the-shelf market showed that the existing alternatives did not meet our requirements both in terms of dimensions and final cost (the example of the considered variant is given at reference []). Moreover, the alternatives considered did not include a cable feeding and winding system that could be operated underwater. Thus, we decided to develop these devices independently. The following criteria were put forward for the final variant of the mini-ROV during the design process:

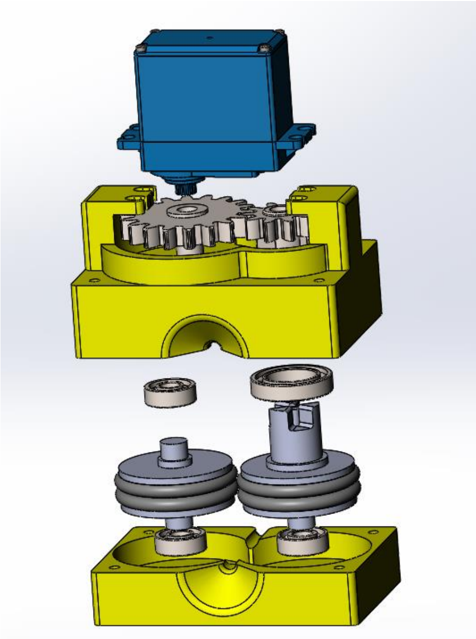


Figure 8.

- dimensions not more than 200 by 70 mm;
- weight in air no more than 0.5 kg;
- the buoyancy is close to neutral;
- the camera on the mini-RoV;
- integrated lighting system;
- no control systems in the mini-ROV housing (microcontrollers, processor boards, etc.);
- the possibility of further extending the functionality of the device.

The limitations on the dimensions of the mini-ROV are due to the need to stay within the allocated limits for the overall dimensions of the launch vehicle according to the competition rules. The close to neutral buoyancy will allow the device to move without hindrance in confined spaces. The camera with lighting system will make it easy to visually detect objects of interest in places with any level of illumination. The absence of control systems in the housing of the mini-ROV will allow the device to function even in case of leaks.

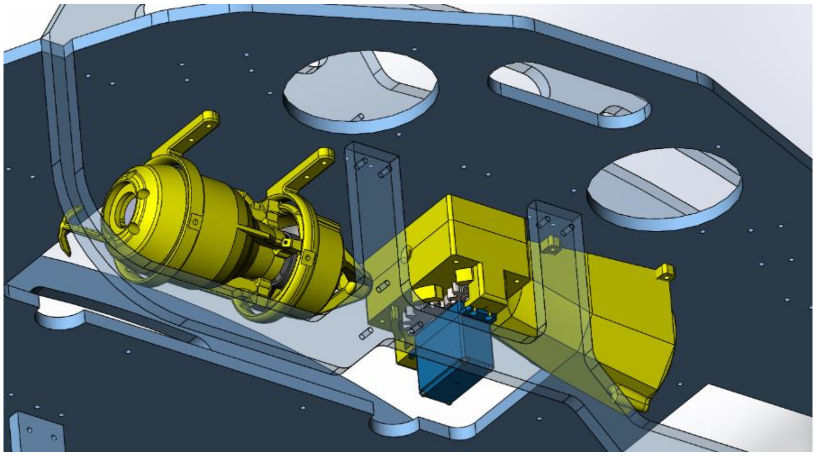


Figure 9.

At first, the plan was to make the body of the mini-ROV either out of aluminum or out of clear acrylic. Due to the fact that at this stage we do not have the equipment that allows us to make the enclosures from these materials, we would have to turn to third-party companies to perform these works. But since we initially assumed the possibility of retrofitting the mini-ROV with various components to extend its functionality, each time we would have to produce a new case for new equipment. So we started looking for alternative solutions that we could implement with our own resources. The approach we decided to use for making the housing of the mini-ROV was to use a method of 3D printing from PLA polymer with a 0.6 mm nozzle, layer thickness of 0.3 mm with 100% filling. The following technological refinements were taken to ensure the sealing of the housing. Inside, the polymer was treated with dichloroethane solvent to exclude the presence of microcracks and pores. In the area of joining of the two parts of the casing, a slot was provided for installation of a sealing ring, which was also made in-house. For this purpose, a matrix was formed using FDM printing technology, corresponding in shape and size to the required O-ring. The matrix was made demountable for removal of a ready product, and also had an input and control opening for pouring of a two-component silicone compound. The silicone resin mixture was treated with release wax to prevent it from sticking to the walls of the matrix. While filling the mold through the filling hole with a syringe, the level of filling of the mold was visually monitored through the control hole. As a result, we got a finished sealing product of the required shape and dimensions. Next, the body of the mini-ROV was glued. A single propulsion system, identical to those used on the main carrier vehicle, was used as the propulsion system. A Foxeer Razer Mini HD camera was used as a video recording tool. LEDs acted as lighting sources ... The miniROV was powered and controlled by a 3 mm Ethernet cable. The assembled miniature is shown on the figure ... Its general characteristics:•

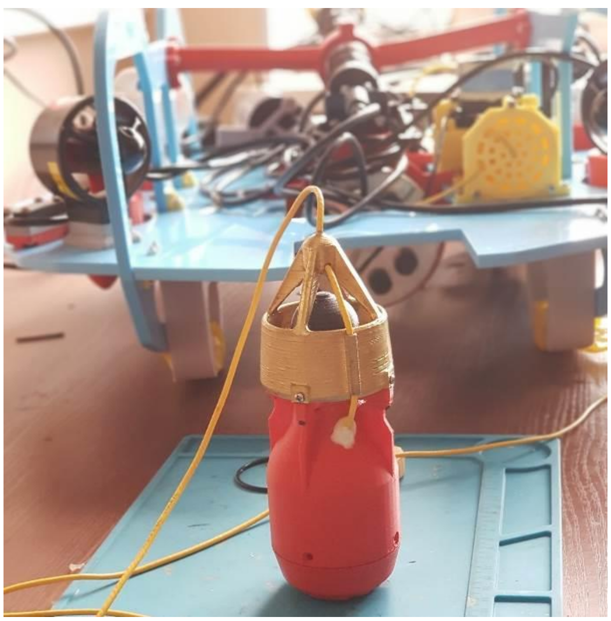


Figure 10.

-Length: 193 мм

- Width: 60 mm

- Weight: 0.3 kg

- Speed: up to 1.5 m/s

- Maximum exit range relative to the ROV: 4 m.

In order to enable controlled operation of the mini-ROV, a cable feeding and winding system has been made (figure ...). This system consists of a servo drive and two gears transmitting the torque from the servo drive to two rollers with 4 specially sized sealing rings, which take the rotation from the gears and pull the cable into a specially shaped container, allowing to lay the cable with even turns.

IX. SOFTWARE

A. Upper-level software

We developed specialized software to control and read the main technical parameters of the ROV. It was written in C# programming language using .Net Framework 4.8 package.

Communication between the laptop running the main ROV software and the Arduino Mega 256 board is via the UDP transport protocol. Every 100 milliseconds, data is timed between the ROV and the application on the laptop of the first pilot. The data is sent in packets, which are an ordered sequence of bytes, each of which contains some value of robot telemetry (if it is a packet coming from the board to the laptop of the first pilot) or control information from the joystick axes (if the packet is coming from the laptop to the ROV). The end byte of each data packet is the CRC value calculated for the packet, which is checked when the packet is received by recalculating its CRC value and comparing the result with the one written in the last byte. All information about the current state of the unit (roll, heading, trim, depth, etc.) is displayed on the corresponding widget in the main application window. If there is no communication, the parameter values remain by default equal to "-".

To interact with the game joystick and get information from it, we use the SFML library (Simple and Fast Multimedia Library) — a free cross-platform multimedia library that is an object-oriented analog of SDL. SFML contains a number of modules for simple programming of games and multimedia applications.

The joystick controls both the device itself (movement along the X, Y, Z, W axes) and rotation of the manipulator claws, their squeezing/unclenching, the rotation to the required angle of the surveillance camera is realized. The created control program allows you to set the thrust limitation on the main axes by selecting 25%, 50% or 100% thrust in the window of the corresponding settings in the main application.

To adjust the depth position of the robot, there is a depth sensor installed on the board and a software function to set the current depth control. In the joystick settings provided in the application, it is possible to change the functions of the axes and buttons by assigning a different control to each action, as well as to invert the directions of the axes.

The most important data values occurring during the current communication session are displayed in the application console, and it is possible to record this data in a log file for later analysis.

The video stream from the front-facing ROV camera is displayed on the first pilot's laptop, in the main application window.

B. Lower-level software

The lower-level code is written in C/C++ in Visual Studio environment using the Visual Micro plug-in. It is fully compatible with the Arduino IDE and uses its libraries and compiler. It can also work with all Arduino boards. The difference between Visual Micro and Arduino IDE is that Visual Micro has all the advantages of a full-featured development environment.

This year, the Arduino MEGA2560 board was used. This choice was made because of the low cost of the board compared to similar solutions offered on the market, the ease of programming and the variety of additional modules for the microcontroller.

A CRC16 is calculated for all packets coming into the ROV, if the calculated CRC16 matches the data from the two bytes of the packet, the packet goes on and is used to update the ROV system parameters.

Feedback is also implemented. Data from sensors (depth sensor and gyroscope) are constantly read out and transmitted to the ground. Where, if necessary, the pilot can turn on regulators, which will assist the pilot in maintaining the set course, roll, pitch, depth. They work on the following principle: based on the data received from the depth sensor or gyroscope, the deviation from the set value is found and the power required to return to the required position is transmitted to the thrusters.

X. PLANNING

A. Task allocation

Teamwork is most effective if it is split into subtasks and there is a defined time to perform the work. In order to organize the work we made a Gantt diagram.

B. Non-technical difficulties

It was not easy to work as planned, for a variety of reasons, and there were times when deadlines for assignments were significantly shifted, which led to a rush closer to the competition. Some members who had been working with us since the beginning of the year sadly left the team, which led to an increased workload on other members. After a long period of distance work, not all students were willing to spend much time in the workshop, which also ended up affecting the effectiveness of the team as a whole.

C. Budget

To make efficient use of the funds allocated for developing, we compiled a table reflecting the price of all the components used in the ROV. Of this cost, some of the components were purchased earlier; however, in order to correctly estimate the cost of the made ROV, we have included the main components used in the summary table.

XI. SAFETY

A. Workplace safety

The working room (robotics lab) supports comprehensive work safety measures. The robotic lab is equipped and furnished in accordance with current standards, rules, regulations and instructions for safe work practices and occupational safety.

Occupational safety training and instruction is mandatory for everyone attending the workshop. Fire safety is implemented mainly by avoiding the formation of flammable or explosive media and sources of ignition. In case of fire, fire protection and alarms are available. The room is illuminated and ventilated so that soldering can be carried out in a healthy way. Any manual physical work is performed only when the conditions of workers' clothing standards are met.

B. Team safety

The most important priority of the team during the development of the apparatus was to ensure the safety of team members at every stage of development in any type of activity. In addition to its direct negative effect, a work injury, in a small team, significantly slows down the pace of work and can worsen team morale.

In order to avoid these complications, workshop safety standards have been developed. To ensure competent work with the ROV in the training pool and at the competition, an analysis of potential hazards was conducted

C. ROV safety

The rules of the competition require that the ROV must comply with a number of safety requirements to ensure that the ROV is operated safely. All dangerous components of the ROV, namely the thrusters, electronic units, and sample collector, were marked with special signs prohibiting them from being touched when the ROV is activated. Access to the propeller blades was restricted by grates to avoid the possibility of anything getting caught in the blades. According to competition regulations, all sharp corners of the ROV have been chamfered, so nothing can be damaged about them. There is a 30A fuse installed on the cable next to the connector.

XII. REFLECTION

Every time, before the next competition we begin to wonder why all this, sleepless nights, endless troubleshooting, water penetrating everywhere, from which it seems impossible to protect delicate electronics, when everything goes a bit wrong as planned. And we find the answer to this question already after the winners and losers are announced, when all the "battles" in the pool are over, there is a sense of overcoming, a taste of a completely new experience, especially when the results are good.

Underwater robotics gave me the opportunity to realize myself, first as an electronic engineer, then as a programmer. After several years of participating in the team, I went to teach robotics to kids. Robots are my Everything!

Oleg Shevchenko - CEO, Programmer

I'm 2 years in the team, and of course got better at creating 3D models, the more so that this year I have regular access to a 3D printer. In the future I also want to get into programming to take everything from this project!

Sergey Sidelnikov – designer

XIII. BLESSINGS

IT IS VERY IMPORTANT FOR US TO FEEL THE GREAT INTERNATIONAL MOVEMENT THAT THE MATE CENTER HAS CREATED, YOU MAKE US HAPPIER BY COMING UP WITH THE RULES OF THE GAME EVERY YEAR AND CREATING A TEAM COMPETITION BETWEEN MANY COMPANIES.

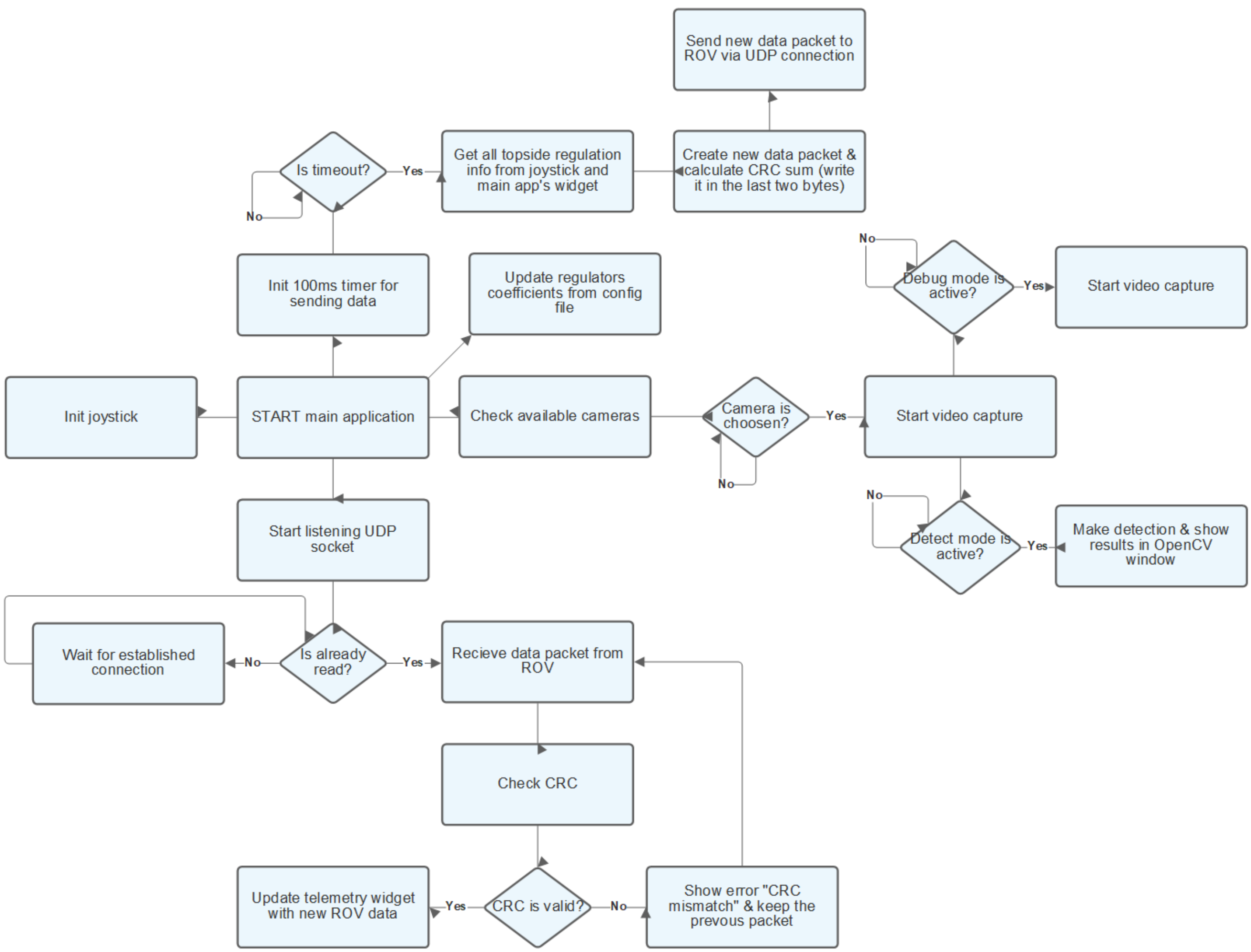
Maritime State University. named after admiral G.I. Nevelsky, where we work and present it for competitions. Thanks to the University's support we can study new equipments and buy everything we need. And also hold unforgettable training sessions in the pool.

"Robotics Development Center" which is a regional operator of MATE and provides comprehensive support to all teams

To our mentors who trained us in the basics of underwater robotics and spent a long time with us.

Structure of the package "Controls -> ROV":

1	2	3	4	5	6	7	8	9	10
Joystick info				Depth and Yaw values		Camera rotation	Thrust regulators	Debug flag	Manipulator rotation
11				12		13	14	15	16
Open/close manipulator				Regulators		Depth coefficint	Yaw coefficient	CRC-checksum	

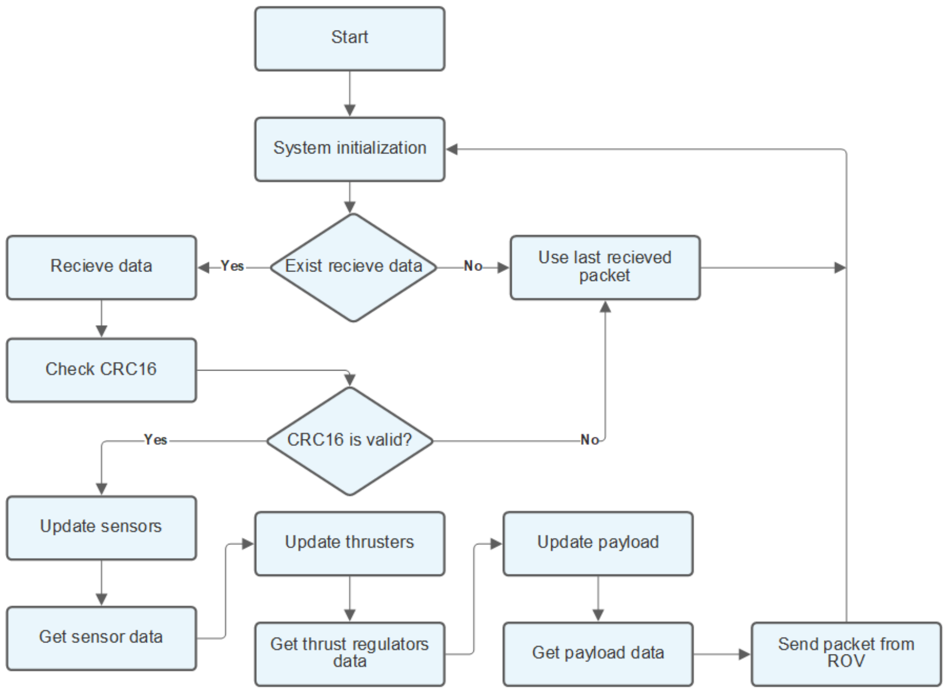


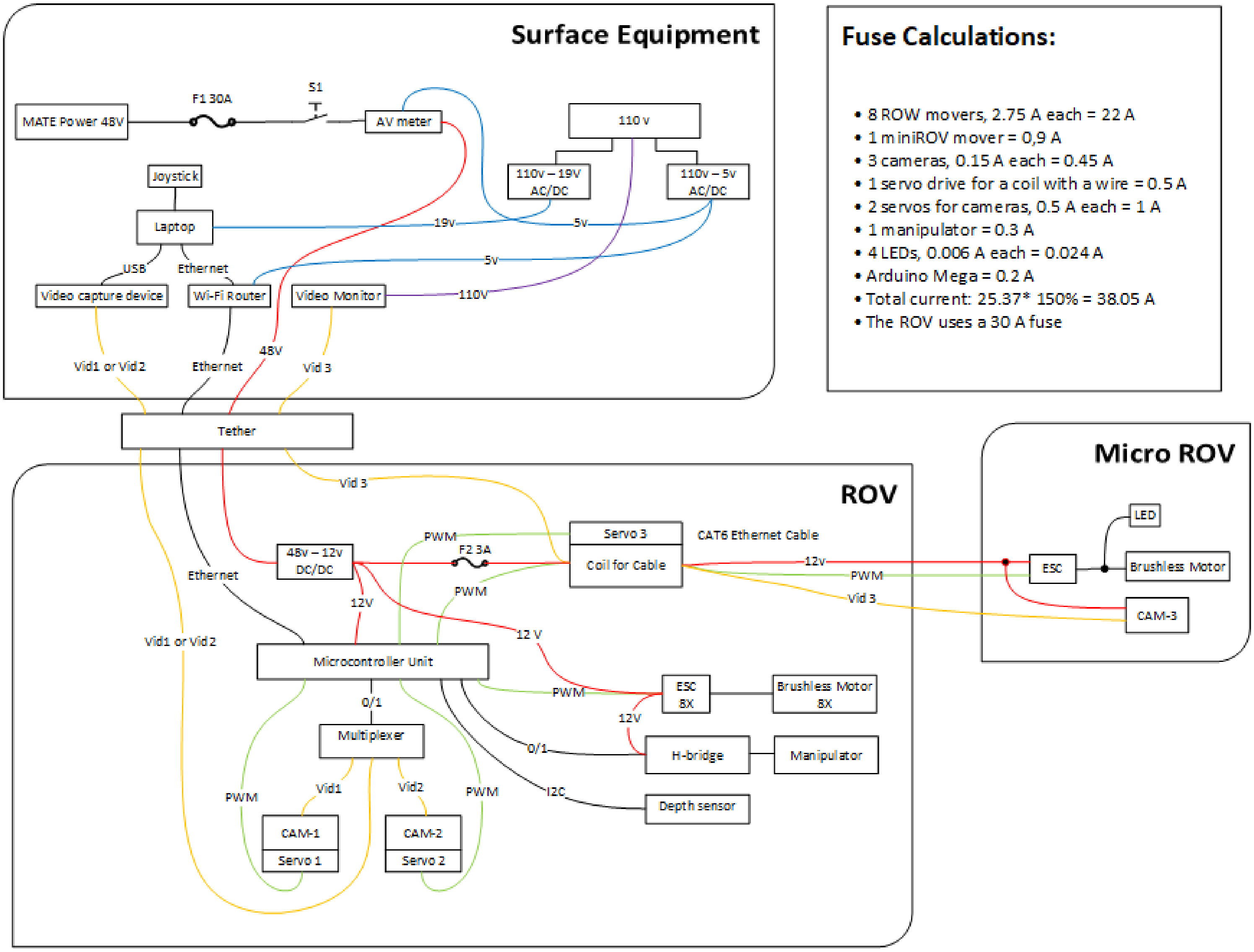
D. Low-level software flowchat

Structure of the package "ROV -> Controls":

1	2	3	4	5	6	7	8	9
Depth	Roll	Yaw	Different	Ammeter	Voltmeter	Regulators	Manipulator's state and angle	

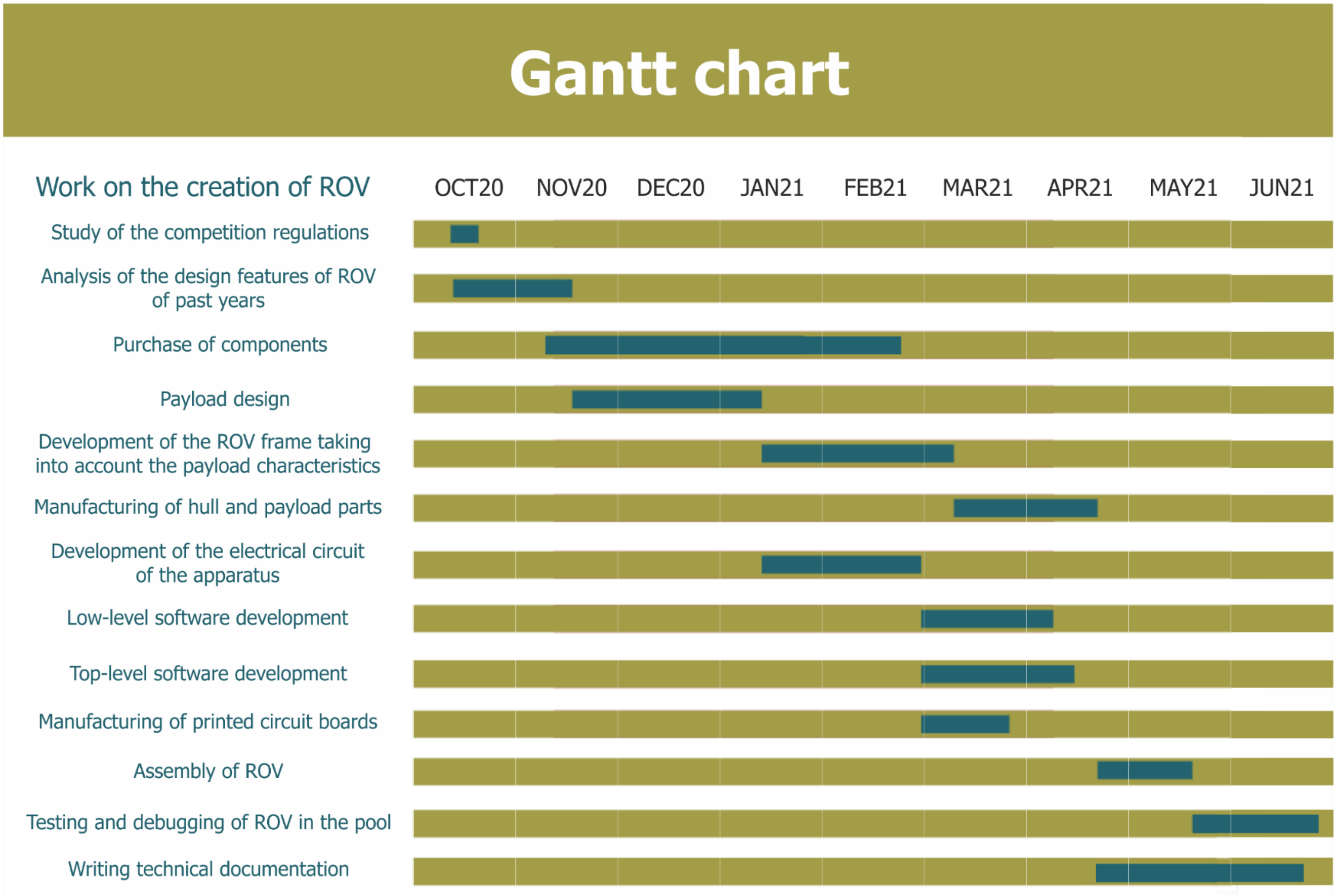
10	11
CRC-checksum	





Fuse Calculations:

- 8 ROW movers, 2.75 A each = 22 A
- 1 miniROV mover = 0,9 A
- 3 cameras, 0.15 A each = 0.45 A
- 1 servo drive for a coil with a wire = 0.5 A
- 2 servos for cameras, 0.5 A each = 1 A
- 1 manipulator = 0.3 A
- 4 LEDs, 0.006 A each = 0.024 A
- Arduino Mega = 0.2 A
- Total current: 25.37* 150% = 38.05 A
- The ROV uses a 30 A fuse


Gantt chart
Work on the creation of ROV
OCT20
NOV20
DEC20
JAN21
FEB21
MAR21
APR21
MAY21
JUN21
Study of the competition regulations
Analysis of the design features of ROV of past years
Purchase of components
Payload design
Development of the ROV frame taking into account the payload characteristics
Manufacturing of hull and payload parts
Development of the electrical circuit of the apparatus
Low-level software development
Top-level software development
Manufacturing of printed circuit boards
Assembly of ROV
Testing and debugging of ROV in the pool
Writing technical documentation