MSU Robotics Team

Maritime State University named after G.I. Nevelskoi,
Russia, Vladivostok

Halcyon

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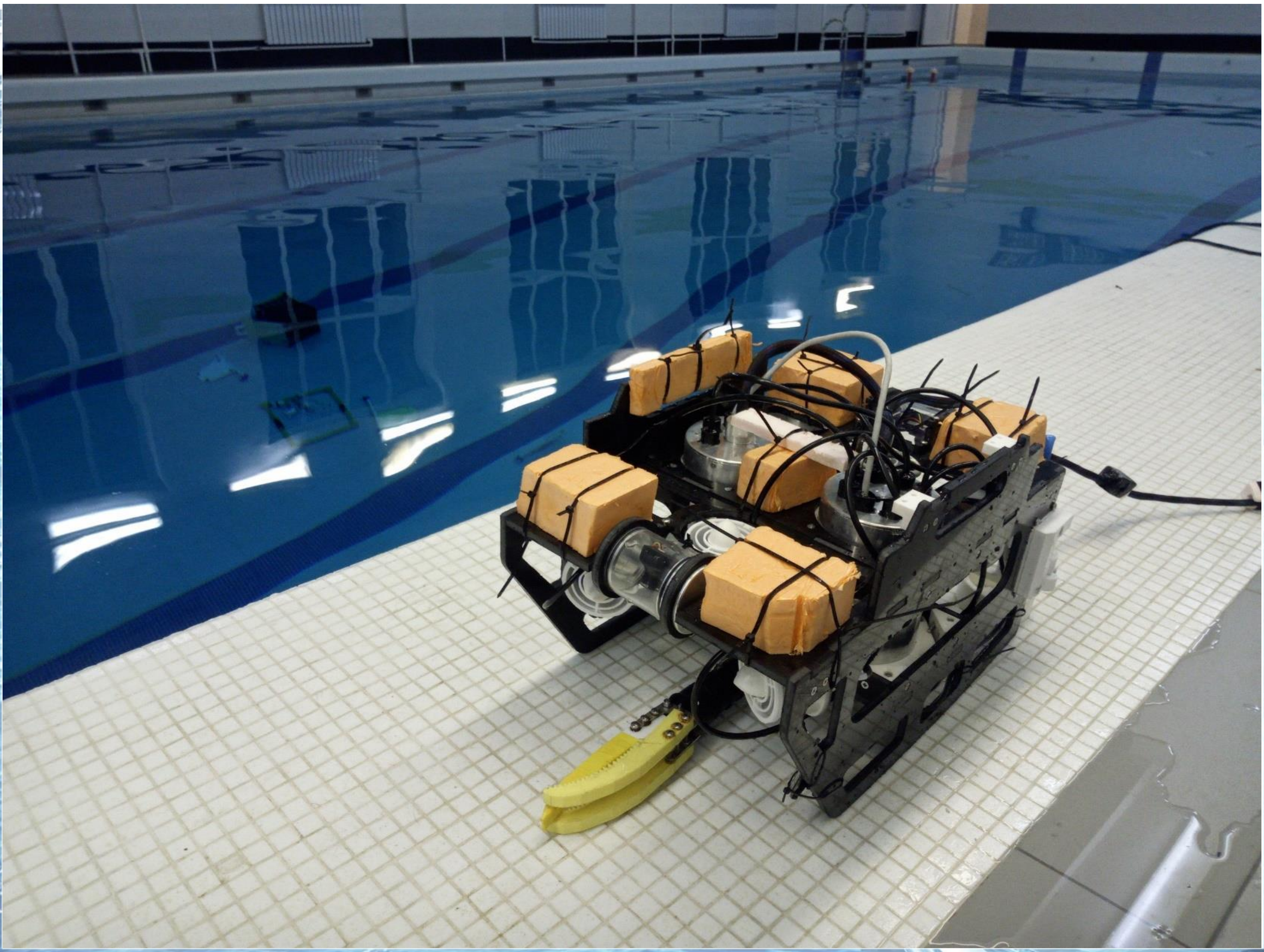


I. Abstract

The primary objective of MSU Robotics Team from the city of Vladivostok, Russia, is to develop effective and reliable solutions for the vast industry sector related to the sea and underwater environment, as well as to follow-up to the initiative of the students and create a strong foundation of scientific and technical personnel in the field of subsea robotics.

MSU Robotics Team presents in this technical report a new multi-purpose ROV: Halcyon. Halcyon is an Explorer class vehicle designed and built especially to meet the challenges outlined in the request for proposals established by The Applied Physics Laboratory at the University of Washington. ROV's characteristics: length: 488,5mm, width: 316mm, height: 296mm.

Rich history and beautiful and lively geography of The Pacific Northwest area of Washington State together with earthquake activity and rapid economic development make this region in need of research and implementation of new technical devices focused specifically on requested tasks. MSU Robotics Team's new ROV is a great solution for many challenges: from installing a seismometer under the water to locating a plane crash and returning plane's engine to the surface.

MSU Robotics Team has come a long way from first brainstorm for new ideas to final completing of the ROV Halcyon. All steps of this way are described in detail and illustrated below. The present document incorporates all about ROV's creation process: early stages of project design, construction, mechanic, electronic parts, payload, software, algorithms, testing and troubleshooting.

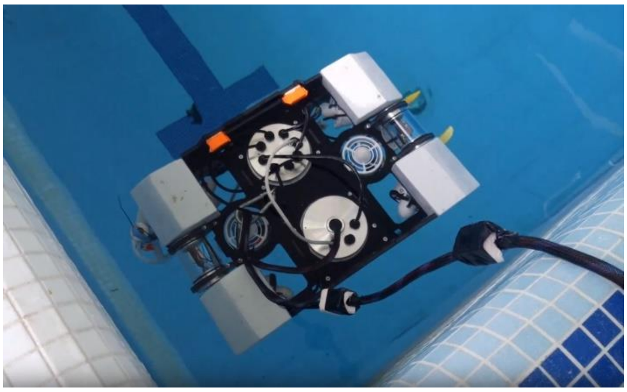


Figure 1. *ROV Halcyon*

II. Introduction

A. COMPANY INFO

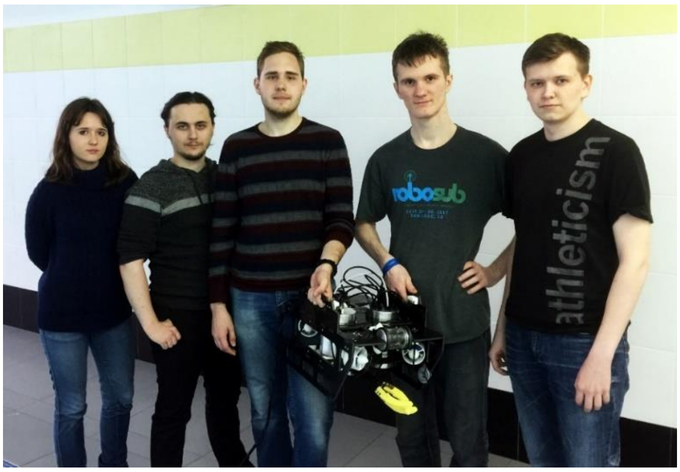


Figure 2. *MSU Robotics Team's picture together*

MSU Robotics Team is the main ROV company of Maritime State University named after G.I. Nevelskoi. The company was created in 2014 and since then it has been successfully operating in the field of developing Remotely Operated underwater Vehicles (ROV), intended for different purposes.

A number of company members renews each year according to year of study of each student: somebody who finished education goes out and another one who just started takes his place, etc.

Now the company consists of a group of students from Physical and Technical faculty of Maritime State University. Despite common faculty, each of company members has his (or her) own specialization so company working together makes it possible to achieve maximum labour efficiency in development process and do a good division of responsibilities between company members in accordance with technical skills and competencies of each one.

B. COMPANY ORGANISATION

Our company is a hierarchically organized group specialized on solving broad range of missions in the field of marine technologies.

In this year for successful collaborative working practices in company all process was divided into blocs based on different areas of science and knowledge. Each such bloc was given for work to company member whom specialization is appropriate for chosen bloc's list of tasks.

Two mentors with larger competence and knowledge were working together with company to oversee the project and give advices for all members on any issues.

Figure 3. *Work process*

Figure 4. *ROV Halcyon in the assembly process*

Company meeting were taking place each week in a specially equipped robotics workroom and at that time, each company member was allowed to give a full report of all the work done during the last week. In addition, deliberations over further goals and missions were held there on the company meetings. Every day company or some of its members got together after the classes for collaborative work and preparing current tasks. Management of works and planning were organized not only by company meetings but also through remote communication by emails and social network.

The important feature of MSU Robotics Team is that its mentors who support students during the work process were also company members in the past. Because of it, they have not only a large technical knowledge base but also invaluable experience working on ROV creation and perfect understanding of company structure that undoubtedly is very important for maintaining the level and preparing new company members.

III. Design rationale

A. USE-CASE MODEL

After lengthy discussions between company members and complicated analysis, a use-case model was created to decide, which device is needed for what task. The results are presented in the table below, where the first column consists of steps of the tasks and the second – shows which tool does the ROV needs to complete the each task.

TASK 1: AIRCRAFT	
Using flight data to determine the search zone for the wreckage	Software, second pilot PC
Identifying the aircraft using the tail section	Back camera, Software, second pilot PC
Removing debris	
Attaching the lift bag to the debris	Manipulator
Inflating the lift bag to raise debris	Mechanical pump
Moving the debris from the wreck area	Manipulator

*Releasing the lift bag from the debris using:	
1. Main version	A frequency-selective acoustic release
2. Additional version	Bluetooth release
3. Backup version	Manipulator
Returning the engine to the surface side of the pool using a lift bag	
Attaching the lift bag to the engine and inflating	Manipulator and mechanical pump
Returning the engine to the surface, side of the pool	Manipulator
Returning all lift bags to the surface, side of the pool	Manipulator
TASK 2: EARTHQUAKES	
Inserting the power connector into the port on the OBS	Manipulator
Lighting the power indicator LED	Show it on front camera
Leveling the OBS	Back camera, Wi-Fi module, motor
Receiving and accurately displaying a seismograph data transmitted by the OBS	
Receiving a seismograph data	Wi-Fi module
Displaying the seismograph on a video monitor	Software, second pilot PC
Create a graph with seismograph data	Software, second pilot PC
TASK 3: ENERGY	
Using tidal data and nautical chart to determine the optimum location for a tidal turbine	Software, second pilot PC
Using tidal current data to calculate the maximum possible megawatt generation at this location	Software, second pilot PC
Installing a tidal turbine in the optimum location	
Installing the base on the bottom	Manipulator
Installing the turbine onto the base	Manipulator
Latching the turbine in place	Manipulator
Installing an Intelligent Adaptable Monitoring Package (I-AMP) to monitor the area	
Transporting the I-AMP to its stand	Manipulator
Locking the I-AMP onto the stand	Manipulator
Placing a mooring a given distance from the base of the tidal turbine	
Measuring the given distance from the base	Software, second pilot PC
Placing the mooring on the bottom	Manipulator
Suspending an Acoustic Doppler Velocimeter (ADV) at a given height on the mooring line	
Measuring the given distance from the bottom	Depth sensor
Attaching the velocimeter to the mooring line	Manipulator

**The best option will be chosen based on the test results*

B. CONSTRUCTION DESIGN

1. Frame

In the development of ROV's frame, the main attention was paid to its overall mass characteristics, ease of maintenance and ease of construction. Polyethylene was chosen as a material for the frame because of its average characteristics in comparison with polycarbonate and polypropylene. The first of them sinks easy and is too hard; the second is softer and much lighter than water, so it was decided to use polyethylene.

Figure 5. *ROV's frame*

The frame was designed with taking into account the following information:

- missions, that ROV must complete;
- payload;
- count of thrusters and their layout.

Figure 6. Details of payload and thrusters

Subject to the above points, carrier and payload elements were posted with SolidWorks program and after that, the frame was designed in accordance to their location.

Mountings for manual deployment of the device were developed to reduce the size of the ROV, and they significantly reduced the size of the frame.

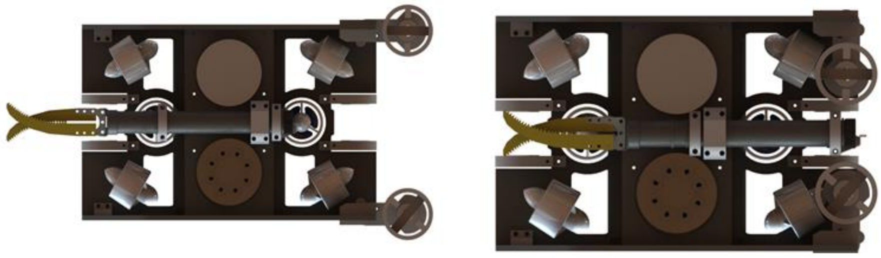


Figure 7. Folded and unfolded state of the structure

2. Thrusters

Last year company faced a number of troubles, including the unreliability of the magnetic coupling design, so it was decided for this year to use a ready-made solution for thrusters. Six three-phase brushless motors, which are free from the problem of full sealing and have the following characteristics:

- Kv 350;
- thrust 2kg;
- operating voltage 12-24V;
- maximum current consumption 10A;
- ESC 30A;
- turnovers 5600rpm.

Figure 8. Thrusters

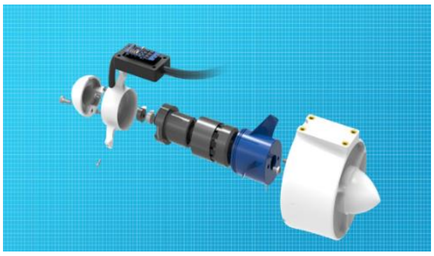


Figure 9. Case-screw system

For convenience in horizontally controlling the ROV, four thrusters turned by 30° outwards, to ensure the possibility of movement across the horizontal axis, the steering stability, and also to reduce interference.

Thruster consists of:

- three-phase brushless motor;
- three-phase brushless motor driver;
- case-screw system.

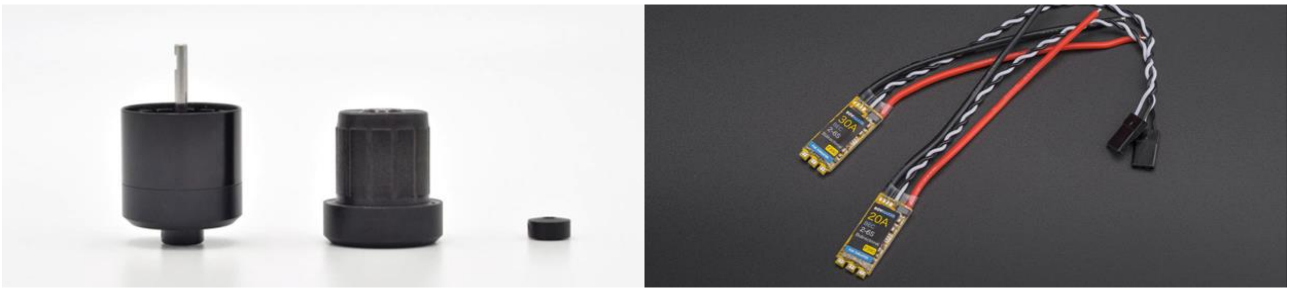


Figure 10. Three-phase brushless motors and their drivers

Figure 11. Two bulbs for onboard electronics unit

3. Onboard electronics unit's bulbs

Last year the company had significant problems with sealing because of old fittings so in this year to eliminate such problems company decided to use next solutions:

- create two bulbs for onboard electronics unit;
- use penetrators instead fittings because penetrators are more safe and ensure more leakproofness;
- check the depth of immersion with Solid Edge program.

C. ONBOARD ELECTRONICS

The main electronic system includes:

- two sealed bulbs with:
    - step-down DC/DC from 48V to 13,8V;
    - microcontroller and additional components for it;
- thrusters - six three-phase brushless motors;
- FPV cameras.

Figure 12. DC/DC transformer

A tether from the control box is wound up in a bulb with a Converter through the penetrator. Here are located two parallel-connected blocks of lowering voltage from 48V to 13.8V, each with an output current of up to 30A. 48V is not found anywhere else. A cable 13.8V is wound up in the next bulb with a microcontroller. A cable with four twisted pairs (two for the cameras, the other two for communication through the router) passes there, through this bulb. The second bulb contains four electronic boards:

- Arduino MEGA;
- WIZnet Ethernet W5100;
- electrical power supply board;
- board for connection of additional devices.

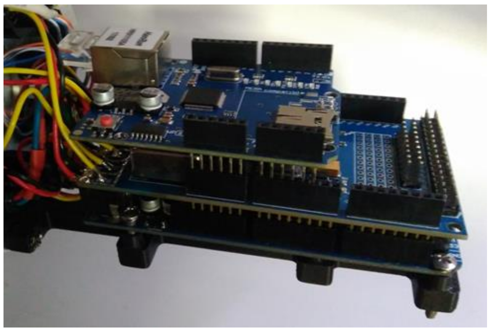


Figure 13. Chassis with a microcontroller, a power board and a W5100

Legs on the chassis printed on a 3D printer join the first three boards together.

The power board contains:

- transformers:
    - for cameras power supply 12V (with galvanic isolation);
    - for power supply of camera servos and Ethernet board 5V;
    - for power supply of microcontroller 7V;
- logical level converter 3.3V – 5V;
- manipulator's motor driver;
- gyroscope and accelerometer.

Multi-channel levels converter TXS0108PWR is used for interfacing the Arduino with a depth sensor and a gyroscope. In addition, there are platforms for soldering the wires of the thrusters (three for each, power 13.8V and PWM); the drivers for the motors are mounted outside on their housings. The board for connecting peripheral devices via a loop is connected to the power board.

Through it are connected:

- manipulator;
- two cameras;
- SparkFun Pressure Sensor Breakout - MS5837-30BA.

Sensor measurement range: from 0 to 30bar, at -20°C to +85°C, with an accuracy of 0.2mbar.

Figure 14. Pressure sensor

D. PAYLOAD

1. A device for rotation the T-bolt on base of the seismograph

Figure 15. *Waterproof housing containing high-speed motor with step-down gear*

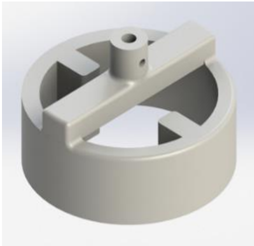


Figure 16. *Torsion nozzle for rotating T-bolt*

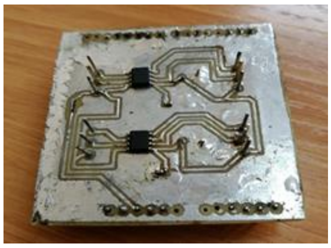


Figure 17. *Power supply board for torsion nozzle motors*

Company decided to use two motors with a reduction gear in a sealed housing to rotate the T-bolt on the seismograph's base. They are connected to the T-bolt torsion nozzle. To power the motors there's used a board of company own production, based on the drivers of the motors A4950. The drivers themselves are powered by 5V supplied from the Arduino MEGA board. The 12V voltage supplied to the drivers is used to power the motors. The nozzle rotates clockwise or counterclockwise, depending on which driver leg has the logical "1", and which has logical "0".

2. Inductive connector

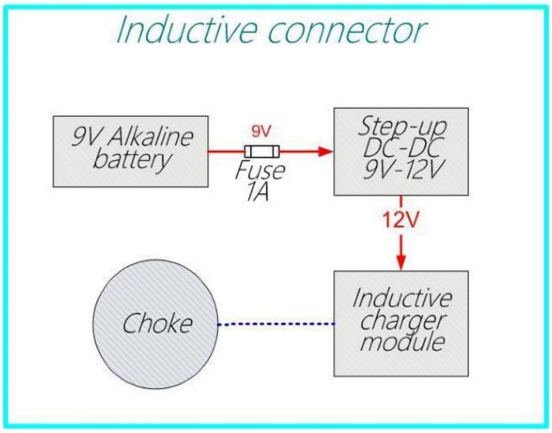


Figure 19. *Inductive connector SID*

Figure 18. *Inductive connector and its housing*

To perform the second task, company was in need to create an inductive connector in a sealed housing. The electronic part of the connector consists of an inductive charging module that raises the DC/DC Converter from 9V to 12V, 1A fuse and 9V battery 6F22. The housing consists of a water coupling and plugs. The inner and lower parts of the body are filled with epoxy resin. This was made for sealing that is more reliable. The structure has a height of 89mm and a diameter of 55mm.

3. Manipulator

The company decided to use the Rovbuilder manipulator with two degrees of freedom for many specific tasks, which full list can be viewed above, in a Use-case model paragraph.

Instead of creation original device or buying new, it was chosen to use last year solution owing to the high cost of the new one and because of a fact that company's old Rovbuilder manipulator was still good in work.

Figure 20. *Manipulator*

Working voltage of manipulator is 12V. The grip strength of manipulator: 7,5kgs. To perform all chosen tasks, the basic claws of the manipulator were replaced with larger ones with a modified geometry with the expectation that they could grab a bulky object and at the same time do not lose the ability to grab a small one.

4. Cameras

Figure 21. Camera

The ROV is equipped with two cameras, back and front, located in cylindrical acrylic bulbs. The servo drive provides one degree of freedom – rotation along the bulb's inner surface (up and down) by 180°. Cameras type - Crazepony FPV Camera JJA-960H HD Cam 2.1 mm with 120° viewing angle. Because of the faults, a similar pair with the following characteristics replaced one pair, the camera and its servo: SONY CCD mini MS1673 and servo Tower Pro sg90.

5. Lift bag

A device for lifting the debris is an inflatable rubber ball with a diameter of 41cm. Its load capacity is up to 10kg. Carbine is made of PVC pipe and rifle, printed on a 3D printer. The carbine is notable for the fact that for the engagement of the U-bolt, it is enough to make a little effort, it does not open spontaneously and can withstand up to 10 kg.

Рисунок 22. Lift bag

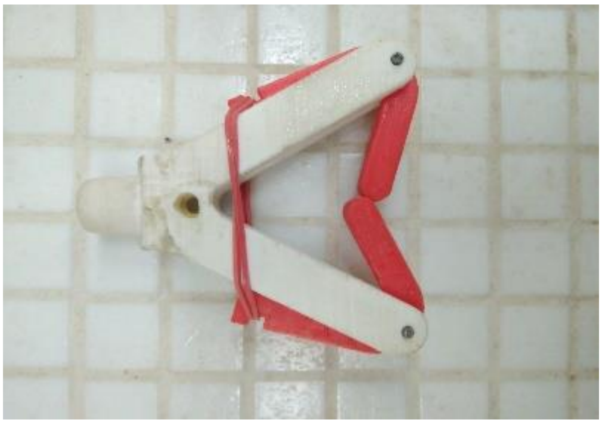


Рисунок 23. Carbine

IV. Control box

Solution that was used last year for ROV's control box, was taken as a basis this year too. Appearance of the structure remained the same, only the internal content underwent small changes.

As before, the ROV control system consists of a shockproof case, laptop, game joystick and monitor.

A. CONTROL PART

The control system includes a laptop and a joystick with five degrees of freedom. All control is carried out programmatically, with the help of a specially designed Application for controlling the robot. There are no relays, variable resistors and other devices allowing control inside the control box. The monitor is used to display image feed from the front camera via HDMI Converter. The image from the back camera comes to the laptop through the video capture device Rombica Pro Studio. Connection between laptop and controls is via a Wi-Fi router.

B. POWER SUPPLY PART

Under the terms of MATE, the power supply was removed from the circuit from the AC. There in the control box was only the second option of power supply - directly from a DC network with a voltage of 48 V (MATE source).

Diode pair 40CPQ060 that was used in order to avoid any conflicts between the sources before, now is used to protect the reverse electric. However, AC power connector continues to be used for some devices. The system also has four switches: one automatic and three switches for different devices.

Figure 24. Control box's internal content

One switch interrupts the power to HDMI Converter (100-240VAC to 12VDC Converter). The other switch closes the Wi-Fi router (100-240VAC to 5VDC). The last switch interrupts the MATE source. The automatic switch stands after the diode pair and interrupts the power supply of the machine with voltammeter.

The system has two fuses:

- automatic;
- 30A fuse, located in the cable for connection to the MATE source. It is located in a special box that allows user to make a quick replacement if necessary, without opening the case of the control box.

All connectors are made on the side of the case for convenience and to reduce the bend of wires. Seven connectors:

- MATE – 48V;
- AC power: 110V-220V;
- unified access to the underwater part of the apparatus for fork 2РМД27Б19Ш5В1;
- three USB outputs (one of them is not used);
- HDMI output.

Signal from the back camera is transmitted over USB to the second pilot's laptop. Data flow from the front camera is transmitted to the HDMI output. All video signals are transmitted over a twisted pair, and Video BALUN (High definition transmitter) is used to avoid interference. They are installed in a pair: one – above the surface and the other - under the water, on the ROV itself.

In addition, the control box is equipped with a voltammeter to assess the current consumption at 48V directly during operation of the vehicle. A separate step-down DC/DC is also installed for its switching on. Thus, all the converters in the control box supply devices that are located only inside the control box, only 48V supplies to the underwater part of the ROV.

The scheme of the control box is presented in Appendix A.

V. Software

A. TOP-LEVEL SOFTWARE

All top-level software is written with C++ language in cross-platform IDE Qt Creator.

1. Main application for operating ROV

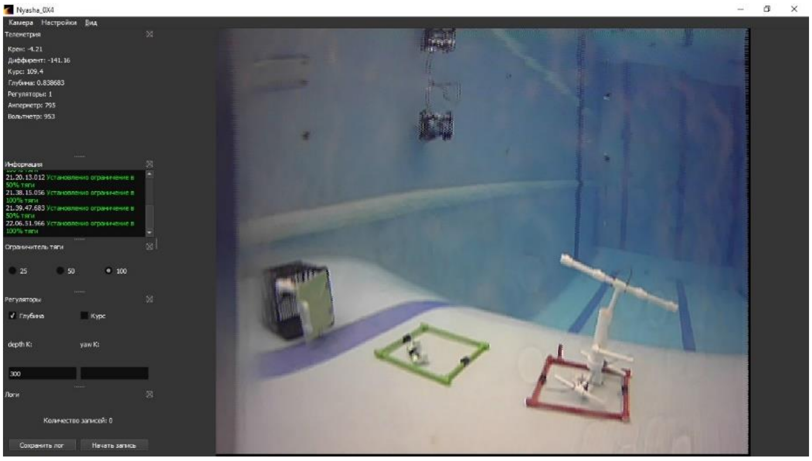


Figure 25. The control Application main window

The main application runs on first pilot's laptop and is used for maintaining connection between ROV and its controls. The link between Arduino MEGA board on the ROV and first pilot's laptop is provided via Wi-Fi. Both devices are connected to common Wi-Fi network and have static IP addresses. Arduino board is physically connected to Wi-Fi router located in the control box, via Ethernet cable. Data exchange between ROV and control laptop is carried out via UDP protocol every 100ms. Datagrams are transmitted in a package format. Every package consists of a strongly ordered sequence of bytes with necessary information (it may be control info if the package is from laptop to ROV or telemetry info if on the contrary). The byte sequence is identically defined on the top level and on the lower level, so interpretation of packages is unambiguous. The last two bytes of every data package contain CRC function calculated for current package. CRC function is using for validating packages.

The first pilot controls the ROV with joystick connected to his laptop. The control Application sets connection with joystick and receives data from it by means of SFML library (Simple and Fast Multimedia Library). This library is an object-oriented analog of SDL library. The main control Application has functions for setting axis constraints to restrict thrust by 25%, 50% or all 100% and for depth regulation. Depth sensor installed on the ROV's board provides data to the top level and this information in conjunction with joystick data is using for depth regulation. This algorithm is realized on top- and lower levels both.

Figure 26. First pilot's workstation

The main Application also has widget for the front ROV camera's data flow. The second camera image displays on the monitor and second pilot's laptop. The top-level software flowchart can be viewed in the end of this document, in Appendix C.

2. Recognition modules for the airplane's tail identification

OpenCV library (Open Source Computer Vision Library) is used in detection algorithm.

First the company developed a separate application for camera image capturing, frame processing and testing of recognition. Later this test app was replaced by its new modified version that consists of three different modes of operation. The first mode is a simple camera view, the second is debug mode with settings widget and the third mode is for real time competition running. In the debug mode, the second pilot can change RGB colors ranges depending on the lighting, real object's color and quality of camera image. The Application runs on the second pilot's laptop.

The company developed two program modules for recognition text and color figures respectively. These are scripts processing camera frame each 100ms. The first script checks frame to find text symbols and returns modified frame with

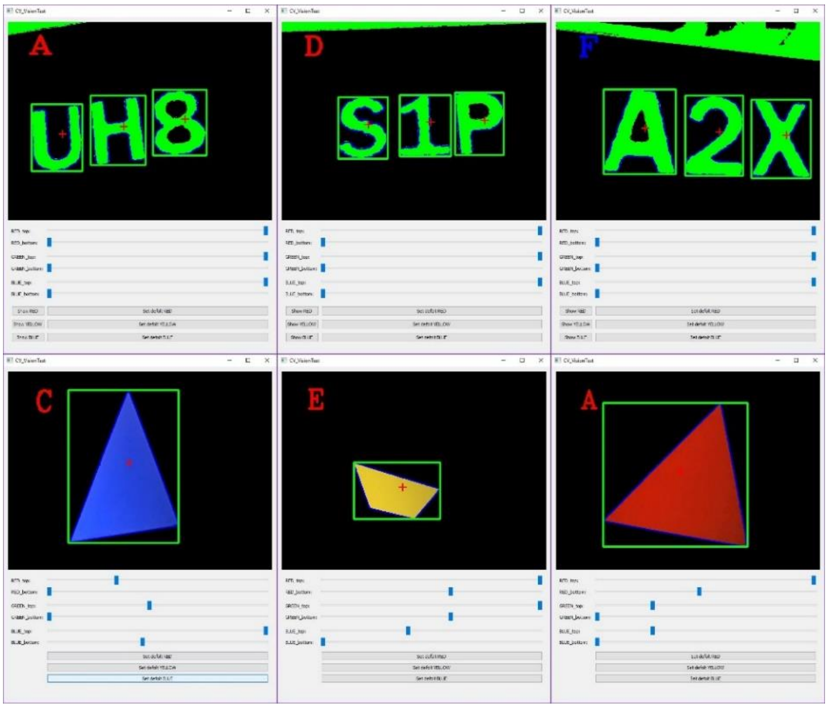


Figure 27. Early detection application examples

typed airplane's ID if there is some text from the necessary list. The algorithm uses letters templates to match them with selected area on the frame. To find letters on frame it is using OpenCV function inRange for black color. There is a breakpoint if the count of selected areas is more or less than three or if their sizes are not correspond to the known text size.

The second script is looking for colors in three different ranges that user can set or change manually. Red, yellow and blue are set on default when program runs first time and after that, every change is accurately saving to a configuration file. When the color is recognized, the next step is to determine the shape of the area. If it is not a rectangle (trapezoid) or triangle, the script returns unmodified frame. The final detection widget shows a frame with recognized symbols or picture from that module which has found a necessary object.

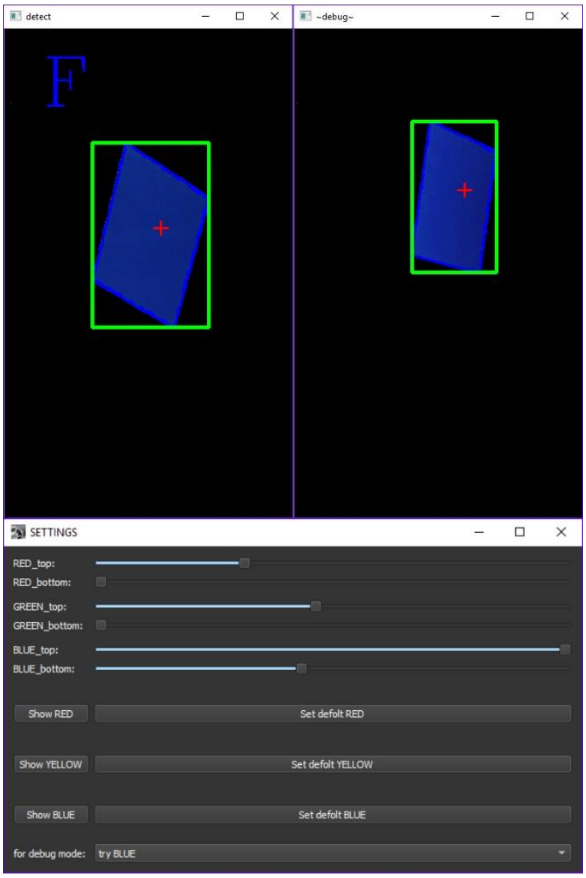


Figure 28. Recognition and debug windows in the final version of application

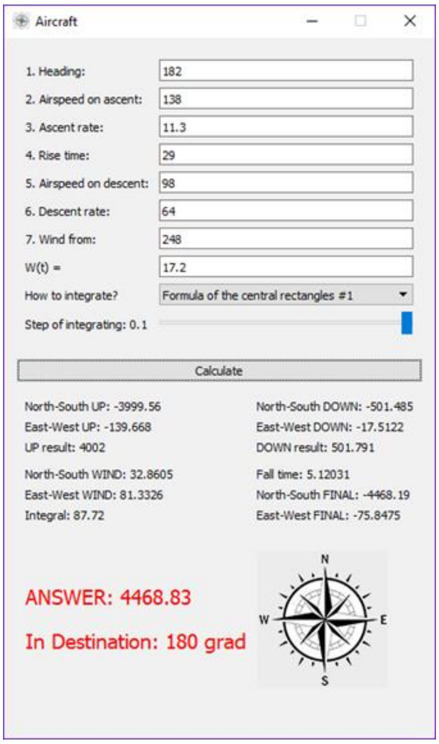


Figure 29. Aircraft Application main window

3. Application for locating crushed airplane

Aircraft Application that also runs on the second pilot's laptop, is a separate unit which operates independently from the main control Application and is using to calculate the site of the crash. It takes the total input data of the flight (as they are presented in the manual) and on this basis producing the necessary mathematical calculations. The results of the intermediate calculations displays in the main window of the application to check work accuracy of the program. It is also possible to select the numerical method for calculation of the final integral (trapezoids method, central rectangles method) and to choose integration step. The result is presented in meters and degrees. The result distance is calculated from the take-off point to the point of fall and the final direction is also indicated relatively to the point of start.

4. *Application for determining the distance from the base of the tidal turbine*

FindTheDistance Application was created to check the distance from the base of the tidal turbine to the given point where is a place for mooring. The Application uses images captured from ROV's front camera and saved to the certain shared folder in the local company network. Company have two ideas how to use FindTheDistance Application: run it on third laptop or leave it for the second pilot attention.

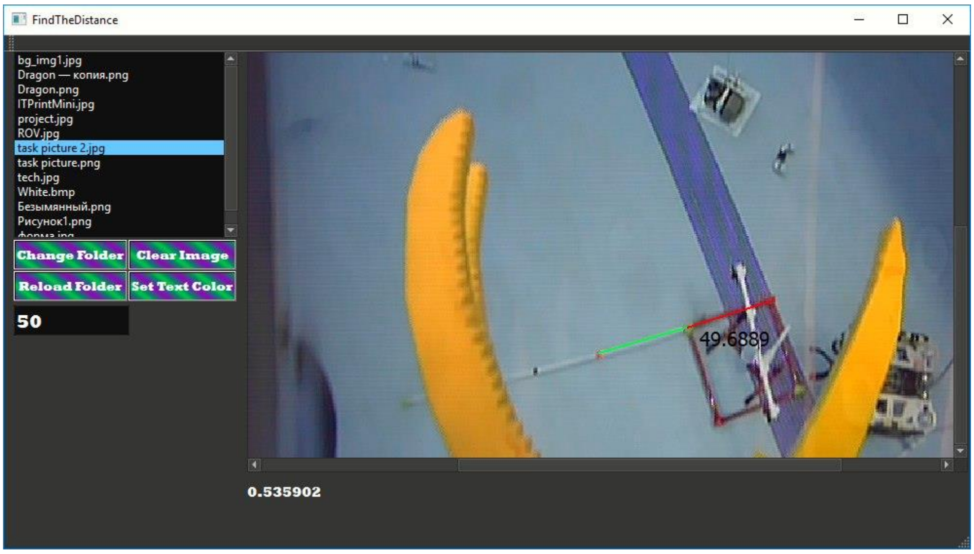


Figure 30. *FindTheDistance Application main window*

The list in the main application window displays the contents of the file directory where the images from the cameras are stored. With one click, a pilot can select a file and open it in the main workspace.

After installing the image to the main workspace, pilot draws by the mouse move first reference line connecting the points of the image. The real distance between the first two points is known, and the pilot sets its actual value in mm in the settings panel. The real length of all subsequent lines drawn will be automatically calculated by the method of mathematical proportion taking into account the length value of each line in conventional units (pt) and the parameters of the first line: the entered real value of the first line in mm and its length in pt.

The length of each drawn line displays directly on the image next to the line itself. This feature facilitates the acceptance of the results and allows user not to confuse the values of the lengths of different lines. The values are not bound to any specific units of measurement, so measurements can be made at any scale. The pilot can clear the image and remove all lines at any time, when he wants, or open a new image. In addition, he can change the value of the first reference line, and thus all other lines will be automatically recalculated with the new value.

B. *LOWER-LEVEL SOFTWARE*

The lower-level code is written with C++ using the Visual Micro plugin.

Visual Micro is a plugin for Microsoft Visual Studio. It is fully compatible with the Arduino environment and uses its libraries and compiler. It also supports all Arduino boards. A difference between Visual Micro and Aduino IDE is in that Visual Micro has all the advantages of a full-featured development environment.

This year the Arduino MEGA Board was used. This choice was made due to low cost of the board relatively to all another, ease of coding and universal support for additional modules and microcontrollers.

A CRC checksum calculates for all received packages. If calculated CRC matches the data from the last two bytes of package, the package accepts and its data uses to update the system settings. In the opposite case, a message about their discrepancy will be sent to the first pilot's laptop. The memcpy function is used to receive datagrams. It copies a memory block of a specified length that is referenced by one pointer, to a block that is referenced by another pointer. Using it instead of the usual assignment of values to variables is because it does not require type conversion, as it works with binary data.

Feedback is supported on ROV's control system. Sensors data and information about ROV's position and its payload are constantly read and transmitted to the top level. If necessary, the first pilot can set on or off depth or yaw regulators. The difference between required position and current deviation is found with the active parameters. Depending on this, power is supplied to the thrusters, sufficient to return to the required position.

The lower-level flowchart is presented in Appendix D.

VI. Planning and process of creation

A. PLANNING AND DISTRIBUTION OF TASKS

In order to complete the work by the deadline and present the ROV at the competitions, the company needed strict planning and accounting for all completed, unfulfilled, common or individual tasks.

At the weekly meetings, each member received a new assignment or comments and guidance from the mentors on the previous one. Throughout the period of ROV developing, the company tried to stick to the plan, which is presented in the Gantt chart (Appendix E).

B. TESTING

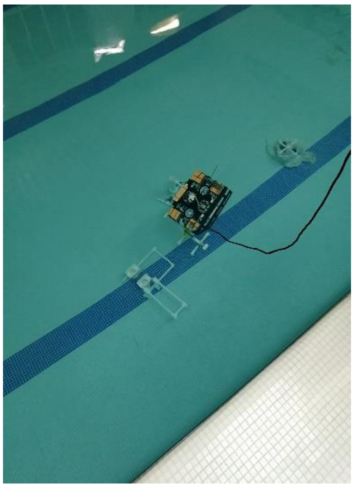


Figure 31. *Vehicle under the water*

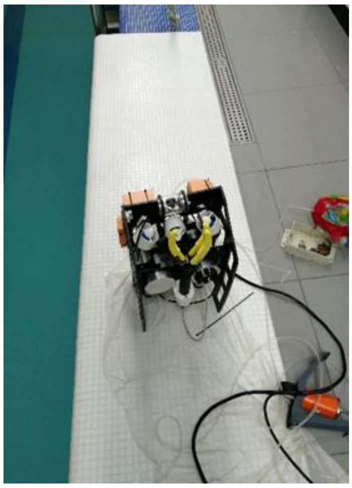


Figure 32. *ROV by the water pool*

Testing in different conditions was carried out both for individual parts of the structure and for the whole device during the process of ROV creation. Tests on flowing all hermetic elements were produced in separate water containers. Tests of the assembled structure were carried out in a real pool before loading the electronics into the autopilot bulbs.

Test runs of ROV in the pool began as soon as the work on the design and electronics was completed, and leakproofness was checked. During the first runs all company members was trying to control the vehicle and the first pilot was chosen according to ability of everyone to drive ROV. The company took about one week to the pilot was able to get used for the new ROV and control it successfully. All company members was developing a special work plan, algorithm of actions to optimize tasks completion process and make the ROV controlling easier and more convenient.

For example, the company found that ROV's cable had not enough buoyancy, it pull the ROV away from yaw so it was decided to add some polypropylene buoys to the cable, and choose someone who will hold the cable during the ROV's diving.

Also during the testing the company realized that it is need to make depth and yaw regulators and them both were developed and included to the main program during the step of testing final ROV.

C. CHALLENGES

In the process of creating the ROV, the company was faced with several technical problems, such as:

- The accuracy of airplane's tail recognition from the camera is largely dependent on the lighting of the room and camera image quality. It is very important for correct work of detection modules written to identify the crushed airplane's tail. Company had difficulties with determining objects even in the usual air environment when the light was changing, and thought about how much trouble can the setting of the process of recognition under the water give, where the camera image is likely to be not as clear as on the surface and have a shifted color spectrum. This problem was solved by introducing additional flexible settings into the program, by means of which it is possible to regulate the process of detecting.
- During camera testing process, the company found that one of the cameras had a servo-drive responsible for turning the camera inside a sealed core. This problem was solved by the purchase of a new servo. After that there were problems with the camera itself (it were showing blue screen every time) so the company replaced it with the new one.

D. NON-TECHNICAL CHALLENGES

One of the main non-technical difficulties was the repair of the educational building, which houses a robotics workroom. Due to the repair heating and electricity was turned off there for a long time that greatly slowed down the work of the company. Because of this, all members were forced to work at home or in free classes in other University building.

The company was trying to get ready for the last testing step as early as possible and it required big effort from all students. To meet the deadlines all company members were staying in the robotics workroom for nights.

E. BUDGET

Item		Count	Price, $	Cost, $
Control box:	Last year solution			
Wi-Fi router TL-MR3020	New	1	34	34
Joystick	New	1	100	100
Voltammeter	Re-used	1	10	10
RSP2000-48	Re-used	1	334	334
HDMI Converter	Re-used	1	40	40
RPC-AC001 Pro Studio	Re-used	1	47	47
Wires, switches	New	1	33	33
Laptop	Re-used	1	334	334
HD monitor	Re-used	1	117	117
Cable	New	1	100	100
AC/DC transformer 220V to 5V	New	1	20	20
Construction:				
Frame material	New	1м^2	42	42
Plastic for 3D printer	New	1	25	25
Autopilot bulbs	New	2	75	150
Thrusters Bluerobotics T200	New	6	500	3000
Mounting	New			33.5
Penetrators	New	21	6.5	136.5
Thrusters	New	4	4.5	18

Material for buoyancy	New			67
Connecting wire	New	10м	3.5	35
Material for autopilot covers	New	4	33.5	134
Frame fabrication		1	150	150
Autopilot bulb fabrication		2	67	134
Autopilot bulbs' covers fabrication		4	33.5	134
Manufacturing of housings for the motors rotating the T-bolt		2	33.5	67
Payload:				
FPV cameras	New	2	25	50
Cameras housings	New	2	50	100
Manipulator	Re-used	1	667	667
Motors for rotating the T-bolt	New	2	13.5	27
Housing for the motors rotating the T-bolt	New	2	33.5	67
Wi-Fi module	New	1	17	17
Pressure sensor	New	1	83.5	83.5
Inductive connector	Created	1	33.5	33.5
Electronics:				
DC/DC converter from 48V to 13.8V, 30A	New	2	33.5	67
Power supply board	Created	1	100	100
Arduino MEGA 2560	New	1	17	17
Ethernet Shield для Arduino	New	1	33.5	33.5
IMU sensor	New	1	50	50
Board for control motors rotating the T-bolt	New	1	33.5	33.5
Other:				
Consumables				84
			Total	6641

Our priority was saving, so we tried to adapt and reuse some components. So it was decided to leave last year control box, manipulator and some other things. However, the main goal was to achieve maximum efficiency, so it was decided to buy more expensive, but high-quality thrusters.

VII. Safety

A. ORGANISATION OF WORK SAFETY

The working room (robotics workroom) supports measures to ensure comprehensive safety. The equipment of the workroom was made in accordance with the requirements of current standards, rules, regulations and instructions of safe working methods and labor protection. It is mandatory to conduct training and instruction on safety for all who visit the robotics workroom. Fire safety is mainly achieved by eliminating the burning possibility of flammable or explosive environments and ignition sources. In case of fire, there are fire protection and alarm systems. The room has lighting and ventilation, which allows soldering without harm to health. Any manual physical work is carried out only under the conditions of workers' clothing standards.

B. COMPANY SAFETY

The most important priority for the company during the development process was ensuring the safety of all members at each stage of development and in any activity. In addition to its direct negative effect, the work injury in a small company significantly slows down the pace of work and can worsen the team's morale. In order to avoid these complications, safety standards were developed. To ensure competent work with ROV in the training pool and at the competition, the analysis of potential hazards was carried out. The results of it were the algorithms of actions drawn up in the check lists that regulate all the procedures for working with ROV.

C. ROV SAFETY

In accordance with the rules of the competition, the vehicle must meet a number of requirements to ensure safety when working with it. All dangerous parts of the ROV, namely the engines, electronics and the device for T-bolt rotation, were marked with special signs prohibiting them from touching when the ROV is turned on. Access to the screw blades is limited by grids to avoid the possibility of getting into the blades of anything. According to the rules of the competition, all the sharp corners of the ROV were worn off, so they cannot damage something. A fuse for 30A current is installed on the cable next to the connector. The control panel is also optimized for increased safety. An automatic switch is installed on 10A-250V – according to our calculations, the total voltage does not exceed this value. Clamps according to the type of voltage separate the wires in the control box: alternating current, direct current and information wires.

VIII. Acknowledgements

We would like to say thanks:

- to the MATE Center, which has united us for the common cause building;
- to the administration of Maritime State University for financial, administrative, technical and moral support;
- to the "Center of Robotics Development" for assistance in providing equipment;
- to all our mentors, who, not sparing any time or money, tried to make us professional developers of ROV.

IX. Reflections

Oleg Shevchenko, electronic engineer: *I came to the team this year as an electronic engineer. This year I was the only one newcomer to the team, but thanks to experienced mentors and team members, I was able to quickly close the knowledge gaps and take an active part in the creation of ROV. This project allows me to learn a lot, and then apply this knowledge in practice. For example, I was able to study the theoretical process of creating boards, and then design and manufacture a board from scratch. It was nice to work in a team of like-minded people who are willing to do a lot for the sake of creating the best ROV.*

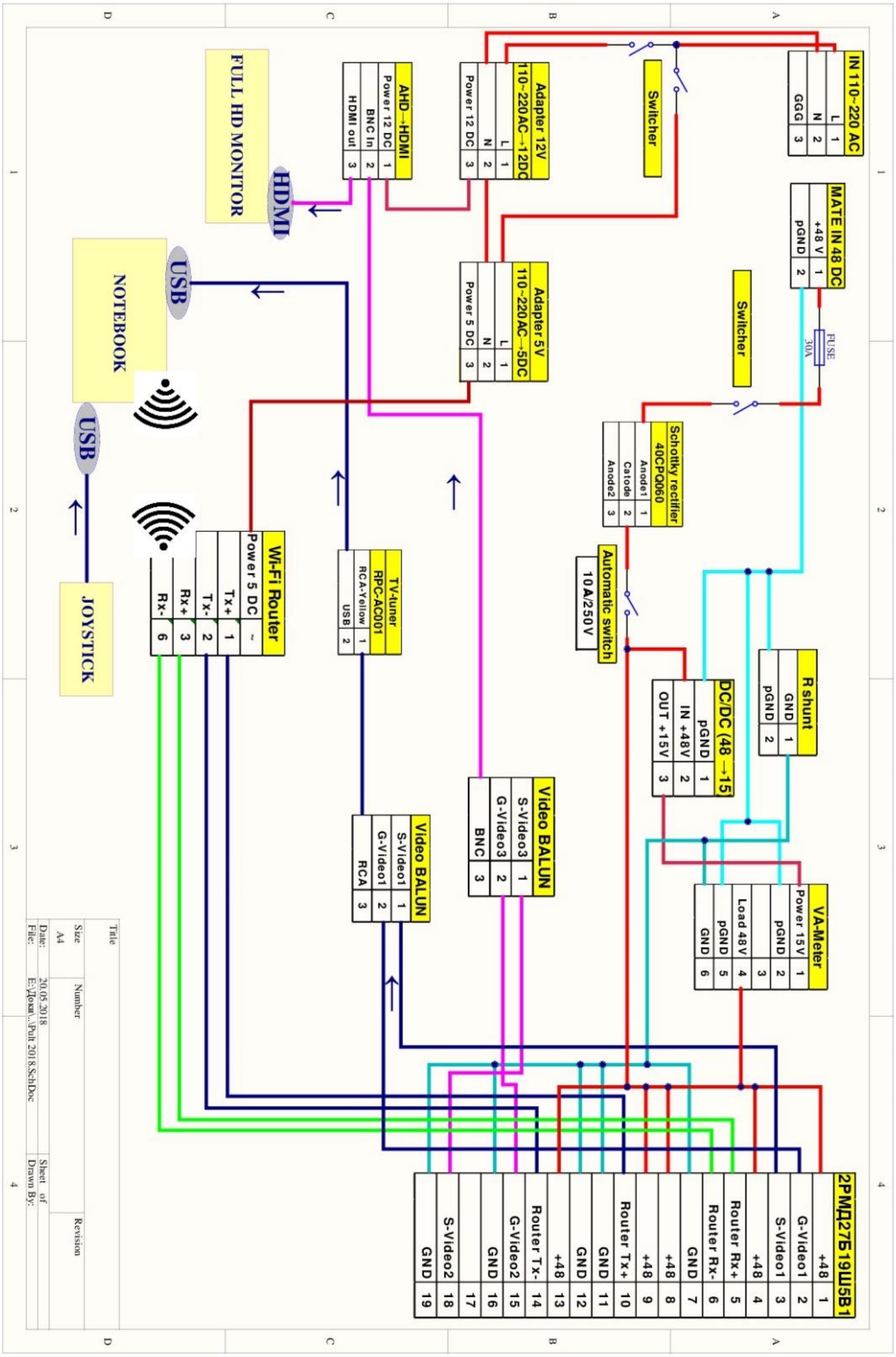
Andrey Bakharev, programmer of MK*: I have been engaged in underwater robotics for the second year as a lower-level programmer. I like doing it. Every time a new task appears, I need to find a new way to solve the problem, a new way. I think it's very interesting. Robotics technology allows you to develop and improve your skills. During this time, I learned a lot about the principles of operation and creation of underwater robots, learned to program various microcontrollers and modules, work in such IDE as KeilUvision, Arduino, Code Composer Studio, Visual Micro. It is especially worth noting the experience of teamwork in such a large project as ROV.*

X. References

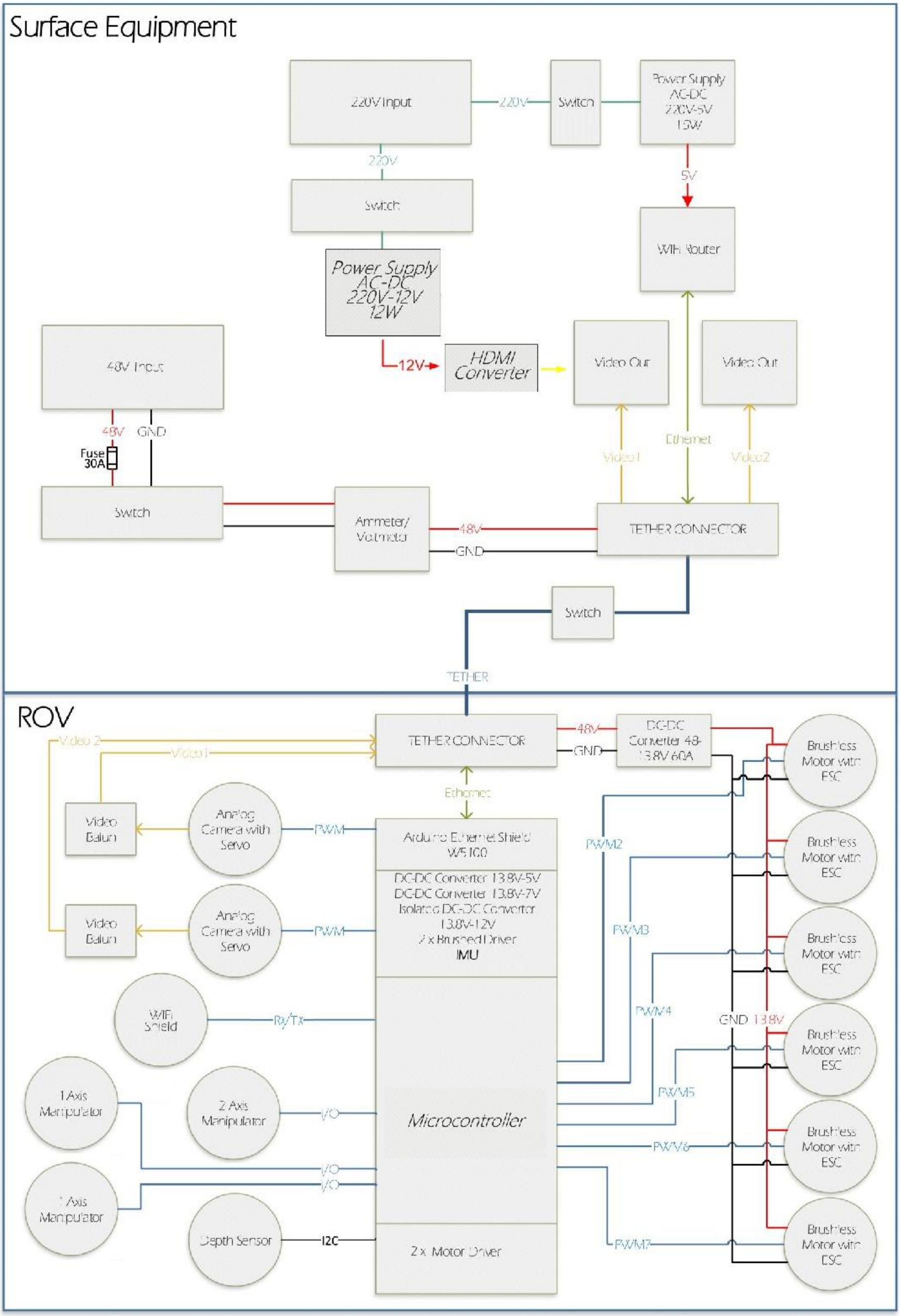
Qt Documentation:
http://doc.qt.io/
http://doc.crossplatform.ru/qt/4.5.0/
Arduino documentation:
http://forum.arduino.cc/
OpenCV documentation:
https://opencv.org/
http://robocraft.ru/blog/computervision/264.html

XI. Appendixes

A. SCHEME OF THE CONTROL BOX



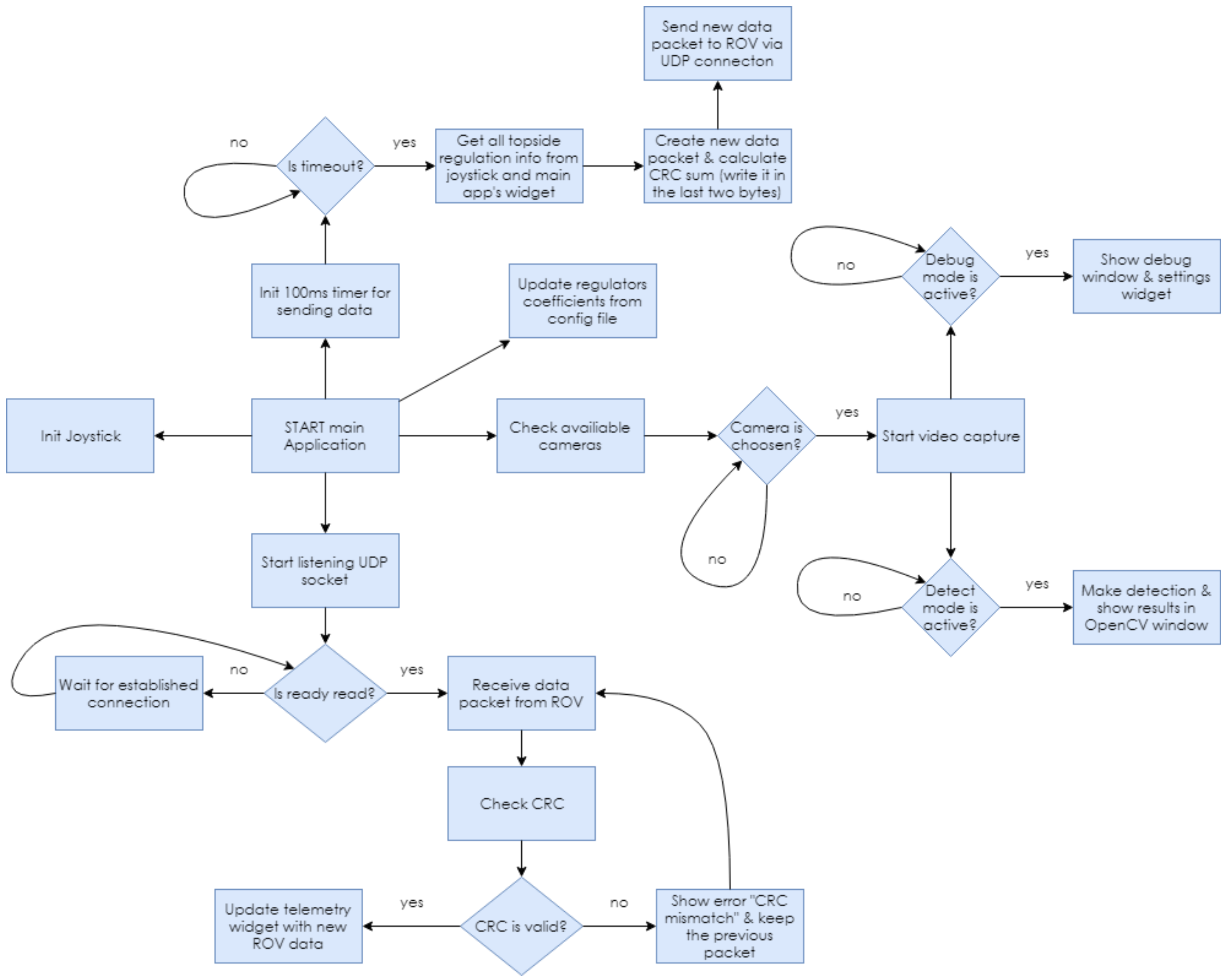
B. SID (SYSTEM INTEGRATION DIAGRAM)



C. *TOP-LEVEL SOFTWARE FLOWCHART*

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 coefficient	Yaw coefficient	CRC-checksum	

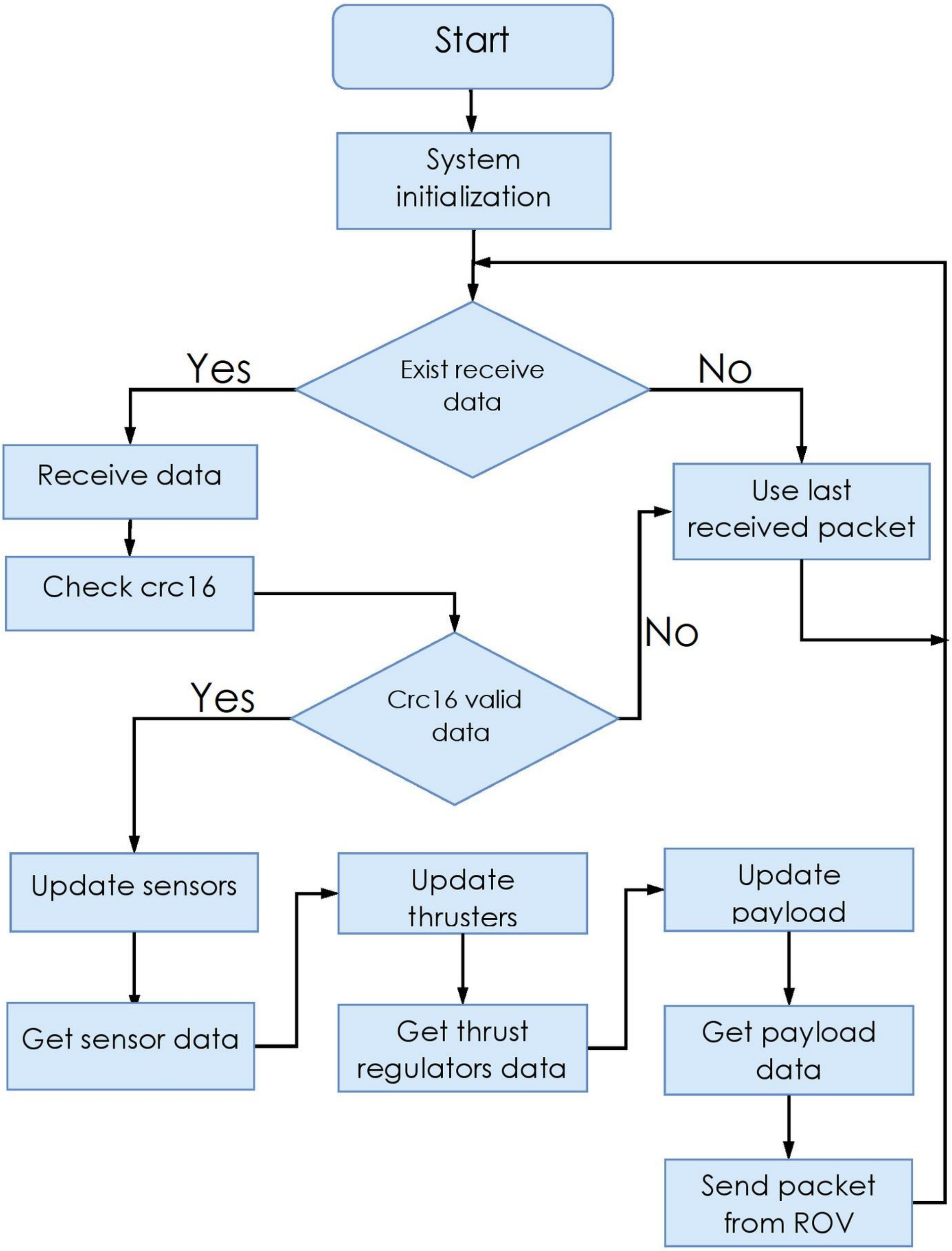


D. *LOWER-LEVEL SOFTWARE FLOWCHART*

Structure of the package "ROV -> Controls":

1	2	3	4	5	6	7	8	9
Depth	Roll	Yaw	Differ-ent	Am-me-ter	Volt-meter	Regula-tors	Manipulator's state and angle	

10	11
CRC-checksum	



E. GANT DIAGRAM