ALIENRAY

The Center rof Robotics Development Vladivostok

company RoboCenter

From the Gulf of Mexico to Jupiter's Moon Europa: ROV Encounters in Inner and Outer Space

RANGER Class

Employees

Electronics

Anton Konstantinov, CEO, 11th grade.
Anton Lobov, Purchasing Director, 10th grade.
Jaroslav Proshin, 9th grade.
Ignat Lebedev, 9th grade.

Programmers

Nikolai Dolzhenko, IT - Director, 11th grade.
Daniel Proshin, 9th grade.
Herman Berdnikov, Designer, 9th grade.

Constructors

Marat Rasulov, Production Director, 11th grade.
Leo Davydenko, Finance Director, 11th grade

Mentors

Sergey Mun
Angelina Borovskaya

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Abstract

Our company RoboCenter from the Center for Robotics Development (Vladivostok, Russia) takes part in the MATE ROV competition for the second time. When organizing our company's work, designing our new ROV and training we tried to use our previous experience and consider last year's mistakes.

Our task was to design and assemble an ROV to perform all the missions presented by MATE: sampling underwater organisms, finding and recovering used satelites, collecting oil samples, studying the underwater world of Europa - Jupiters moon, measuring the tempertaure of water flows, laying a cable and decommissioning an oil platfrom. Due to the fact that most of our company is going to participate in the EXPLORER category next year, we had to prepare a team of newcomers, to participate in next year's RANGER competition. The result of our work is the ROV "Alien ray", that has 4 horizontal and 2 vertical motors, two static and one rotating camera, a main and bottom manipulator.

In the proccess of developing and manufacturing the ROV we learned how to use proffessional design, development and prototyping tools: CAD SolidWorks, a 3D printer, Altium Designer, Qt and Arduino IDE.

As a result, our company has developed a vehicle capable to perform all the tasks that are provided by MATE, and was able to prepare the newcomers to work independently in next year's competition.

Fig. 1. Company RoboCenter. Left to right standing: Marat Rasulov, Daniel Proshin, Ignat Lebedev, Leo Davydenko, Nikolai Dolzhenko. From left to right sitting: Jaroslav Proshin, Anton Konstantinov, Anton Lobov, Herman Berdnikov

Budget

Item	Amount	Donations, USD	Donations,USD	Donated/Reused
Frame				
Water jet cutter	-	246	246	
Turning works	-	62	62	
Polypropylene sheet	1	177	177	
Aluminum pipe	1	9	9	
Aluminum rod	3	8	24	
Fasteners	-	47	47	
Sanding sheets	6	2	12	
Surface equipment				
Case	1	46	46	Donated
Power Supply	1	43	43	
Matrix	1	54	54	
LCD controller board	1	22	22	
Nettop	1	331	331	
Relay	2	5	10	
Voltmeter	1	15	15	Reused
Thrusters				
Motor driver	4	46	184	Reused
Propelling	6	77	462	Reused
Sealant	1	20	20	
Buoyancy and cargo				
Extruded polystyrene foam sheet	1	20	20	Donated
Lead	1	6	6	Donated
Caulking	1	5	5	
Paint	2	17	17	
Primer	1	5	11	
Tether				
Components for cable	-	154	154	Reused
Silicone tube	20	4	80	
Video system				
Analog camera	1	38	38	Reused
Acrylic pipe	1	62	62	Reused
The chamber in the housing	2	17	34	
Servo	1	6	6	Reused
Payload				
Manipulator	1	769	769	Reused
Temperature sensor	1	2	2	
Bottom grabber	1	12	12	
Servo for the botton grabber	3	16	48	
Electronics unit				
PCB sheets	4	2	8	
Epoxy	1	23	23	Donated
Depth sensor	1	31	31	Donated
Arduino Uno	4	6	24	

Navigation-sensor	1	11	11	
Current converters	1	1	1	
Arduino Ethernet Shield	2	10	20	
Grease	2	22	44	
Connectors	1	11	11	
External USB-hub	1	8	8	
TOTAL for ROV			**3 190**	
Miscellaneous				
Taxi	20	200	4000	
Air Tickets	10	1076	10760	
US Visas	10	160	1600	
Accommodations (rooms)	3	520	1560	
TOTAL for all			**21 110**	

Summary table (ROV)

The ROV budget this year, USD	1494
Donated, USD	126
Reused, USD	1570
Total ROV budget, USD	**3190**

Time

Company / employee	Hours
Pool provided by MSU. adm. GI Nevelsky	62
The workshop provided by the Centre for Development of Robotics	3600
The time spent by employees to participate in the project	6300
Mentros (average)	300

The budget was already planned by us, also the use case model was developed, and payload was selected. We defined the budget after we analyzed the market and chose the components. In this year the budget was $1494.

The finance was provided by The Center for Robotics Development. We reported about each expese to the director of the center. Also we kept strict records and all expenditures were presented in a Google-table.

We had to buy some elements, because we don't have the experience to make them ourself, for example: cameras, converter, sensor, etc. But all of these were tuned hard.

We used a taxi-service for transporting devices to the swimming pool (for testing and training), and other stuff of large size to the repair shop. Sometimes we stayed too long in the repair shop, and public transport was not available, so we had to call taxi.

Due to the reason that all materials were bought with a stock and some electrical boards and components were broken during development, the final price of the device is less than we spent, $3190.

Safety

In the development, manufacturing and testing proccess of the device, we have set the safety of employees and the people around them to first place. Firstly, the mentors held different types of briefings for us:

- Briefing on the work in electrical shop
- Briefing on the work in the studio
- Briefing at work in the pool
- Briefings on working with power tools
- Instruction for metal smelting

Secondly, we have developed a protocol for checking the vehicle before, during and after the operation of it in the pool.

Third, for the safe operation of the machine we made it with no sharp corners, put the fuse in the 25A, sound warnings and alarms to the remote operator, leakage sensor in the electronics unit and the rotary chamber, set the grids on propellers.

Fourth, while working in the pool we always determined who will be a senior staff member in the group. He had to deal with the planning and organization of the work of the operational group, as well as to monitor the safe operation. discipline and technical regulations, including filling in protocol.

Before dive (before turn on)	✓	**During operation in the water**	✓
Check the fuse		Tracking leakage sensor	
Check all connectors and wires		Tracking data from navigation sensors ROV	
Checking fixtures		Tracking current and voltage	
Before dive (after turn on)	✓	**After dipping**	✓
Checking the current and voltage		Check for mechanical damage	
Checking leakage sensor		Check all connectors and wires	
Data validation with ROV navigation sensors		Checking the integrity of movers and manipulators	
Checking the camera			
Check propelling and manipulators			

Vehicle systems

Before beginning of developing the vehicle for competition of this year, we have properly studied rules. After that we divided into 4 working groups, and each group has developed the option of use-case model. In them the sequence of a performance of the mission, necessary additional devices (payload) and options of their execution have been defined. We analysed all use-case models, have selected the best solutions of subtasks in each of them and, having carried out brainstorming, have made total option. And then on his basis have developed technical requirements to the ROV and to payload.

One of the main requirements was to make the device as little as possible easier as according to mission of MATE it will be started in space. And start of each additional kilogram costs NASA more, than 20000 US dollars. As for passing of technical control at competitions the device has to fit into the circle of 75 cm, we have decided to make our ROV round, with a diameter of 60 cm. But after carrying out regional competitions we have made the decision on alteration of the vehicle, for receiving bigger number of points for the weight and the sizes. As a result we managed to enter the ROV in the sphere of 54 cm (these are 10 additional points), because of movement of propellers is closer to the center of symmetry of ROV, and also than reduction of edges.

Frame

After we discussed the technical requirements for the ROV, the number of the main devices and payload capacity, our designers started developing a frame for the ROV. Samplings of that equipment which remained from last year were carried out at first: the main manipulator and thrusters. After we began to test different layouts of payload capacity, for more effective implementation of missions. The construction of the ROV was improved and changed in the course of development/purchase of devices, for example alteration of buoyancy of the ROV, because of the installation of the bottom manipulator by the end of trainings. Therefore development of a frame and buoyancy was complete practically along with the end of design of ROV devices.

Our frame consists of the bearing plate which protects thrusters, and baffles between of two longitudinal ribs. In the process of designing the frame we tried to use last year's experience of design.

Last year’s ROV sagged under the weight of the base plate of electronic unit and thrusters, so this year we decided to make the longitudinal ribs in the form of a rectangular framework for supporting the carrier plate.

This year for manufacture a frame and own clamps for the purpose of reduction of weight we decided to use 10 mm sheet polypropylene (910 kg/m3), but not 12 mm polyethylene (965 kg/m3).

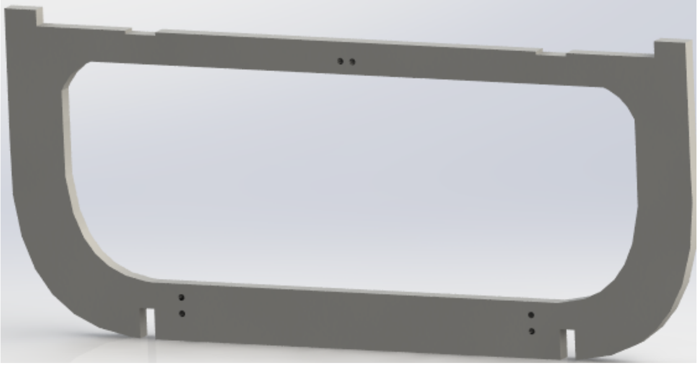


Fig. 2. Model of rib

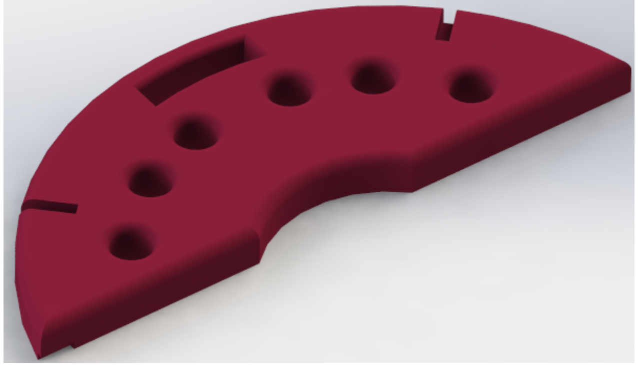


Fig. 3. Model of buoyancy

Buoyancy, as well as the frame, we have designed in SolidWorks. As for calculating the size of buoyancy we would need to know the weight and volume of all the devices and device components, we have designed it last.

As a material for the manufacture of buoyancy we chose 30 mm of extruded polystyrene foam sheet, as it is characterized by a low density (35 kg / m3), zero water absorption, high chemical resistance, resistance to rotting and fungus. We decided to do the buoyancy in two halves, so you can retrieve the electronic unit and remove the vertical thrusters, without replacing buoyancy.

Platemaking buoyancy technology:

Cutting the desired shape from a sheet of extruded polystyrene;

Puttying;

Grinding sandpaper;

Priming;

Painting.

We used lead weights for ballasting ROV, that were casted from the piece of sheet of lead. We put them on the edges of the vehicle for ballasting and greater stability.

Fig. 4. Marat and Leo are making buoyancy

Propulsion system

Thrusters - one of the most important parts of vehicle, as speed and quality of performance directly depend on them. We are using commutator motors, placed under 45 degrees relative to the main axis, because in that year missions are performed on a small square, and all objects are in small distance between each other. That makes vehicle more maneuver in comparasion with placing thrusters under 60 degrees. Direct thrust is 1.6 kgf, reverse thrust - 1.3 kgf.

Our company decided to keep on thrusters from last year, as it’s one of the most expansive parts of our budget.

But, we considered experience from last year and finished thrusters off, installing between contacts of thruster 1mkF capacitor to reduce high-frequency noise, which created by the propulsion system.

For the controlling propusion system we are using Polulu Dual VNH 5019. That motor drivers was selected because of some adventages: at first one board contains 2 drivers at once, that reduces size of Electronics Unit, and at the second, they could provide 10 Ampers, that enough with the stock for controlling our Propulsion system. Also as motors, we used that drivers last year and they proved their reliability and operability, so we thought that there is no need to waste budget and buy a new ones, that is why we used them again.

Video system

The video system is the primary sensor of our vehicle, so the camera should be enough to provide an overview needed to control the ROV. The issue position and number of cameras was resolved after we have decided on the placement of the payload.

We installed one camera in front and made it turning as the anterior chamber (the front camera) should be at the same time provide the best possible overview and "look" at the gripper and at the bottom gripper. From the outset, we would like to make your own camera, but during the development phase, we abandoned the idea because of the small amount of time and knowledge in this area. When choosing a camera, we were guided by the following criteria: size of the camera, the size of the matrix, the viewing angle and light sensitivity. We decided to leave from last year camera because it satisfies our needs, and buying a new one would entail high costs. So we decided to take and greatly modify last year's camera.

As a rotating camera, we used last year's frameless camera 1/3 "SONY EXMOR IMX138 (800 TVL), is characterized by high-definition images. Then we designed the hull and mount in Solidworks. Production of acrylic housing we ordered, and mount the camera to a mini servo we printed on the 3D-printer.

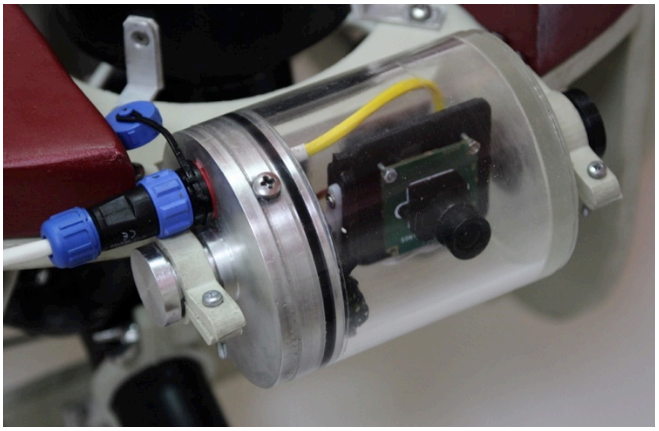


Fig. 5. Rotating camera

Electronic unit

This year we have a new electronics module, it has been designed with chassis which we, taking into account the errors of the past year, designed collapsible for easy retrieval of circuitry. Within the electronics unit all curcuits are attached to the chassis. They are easily extracted from the container, which makes it easy to carry out electrical installation and repair of electronics. Housing unit was developed in the SolidWorks , but was ground in turnery since we do not have the equipment and experience to do it. The body is made of aluminum tubes and caps are made from aluminium bars.

The structure of the electronics unit includes the main control board, an ethernet board, motor drivers, a multiplexer, a depth sensor and a navigation sensor.

As the main control board, we decided to use an Arduino Uno. It is a cheap, compact, and widely distributed. To communicate the main board with the surface we use an Arduino Ethernet Shield. It is also cheap and it only slightly increases the size of the Arduino Uno.

To reduce the thickness of the cable, we decided to transfer the video from three cameras over to a single twisted pair. To do this, we had designed a new Multiplexer AD8184ARZ, which allows us to switch between video streams.

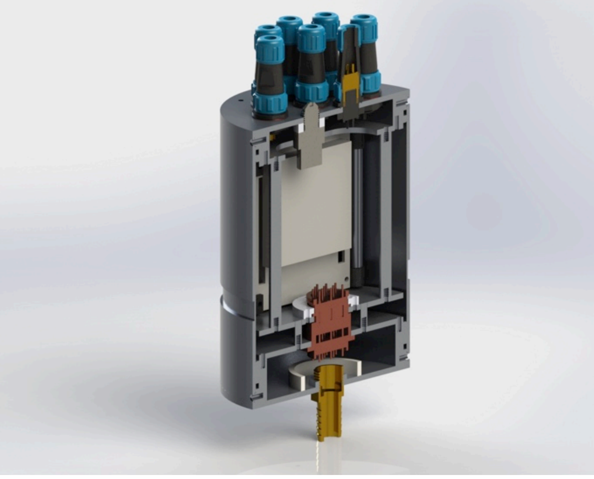


Fig. 6. Model of electronic unit

Navigation Sensor

To determine the position of our vehicle we use a 9 Degrees of Freedom (9DoF) Inertial Measurement Unit (IMU) Adafruit LSM9DS0.

This sensor has been selected because of accuracy in measurements, availability of educational materials and also because of smaller size in comparison with its alternatives.

In the process of working with the sensor we learned the Madgwick Quaternion filter, Euler angles and SparkFun's LSM9DS0 library, which has a lot of positive reviews.

To correctly determine the vehicle's position in current time first we poll the sensor via I2C, then calculate Euler angles based in the raw sensor values. We use these angles for auto-yaw, auto-pitch and to synchronize the position of the 3D model of the vehicle.

Depth sensor

To measure the depth of the ice crust and ocean depth, we decided to keep the D0,1T-4 depth sensor from last year because it proved itself well last year, with the most accurate values in comparasion with its alternatives. Also, the sensor has a number of qualities, that would be useful for our vehicle if it really flew to Europa (Jupiter's moon):

- Resistance to high temperatures;
- Radiation resistance;
- Temperature compensation;
- High overload abilities;
- High elastic features;
- Neutrality to agressive environments.

As the sensor only returns the pressure it is subjected to, we used a formula to get the depth in meters:

$$h = \frac{p}{\rho g}$$

where P is the pressure, p - density, g - acceleration of gravity.

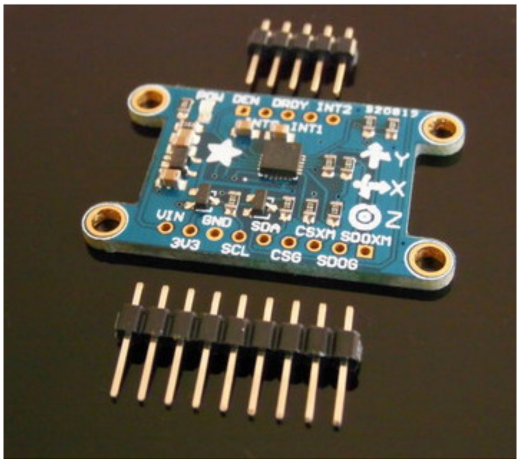


Fig. 7. Sensor LSM9DS0

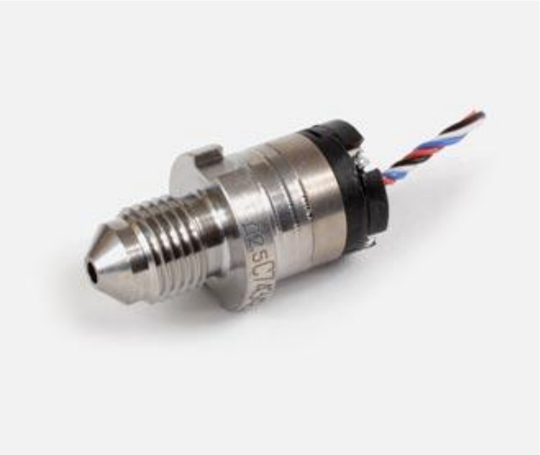


Fig. 8. Depth Sensor

Tether

To connect the vehicle to the surface equipment we manufactured tether. It is a patch cord and two power wires stretched in a silicone tube.

The power cables were chosen based on the ROV consumption. It was necessary to pick up the tether, corresponding to two conflicting requirements:

1. Sufficient thickness did not appear to network congestion. We calculated the required section thickness on the basis of the formula: S= (2pIL) / (Ustart-Ufinal), where S - the required cable cross-section; p - resistivity; Ustart - voltage power supply issued; Ufinal - the voltage at which the device operates; I - load current; L - cable length

2. Maximum thin to reduce the weight and flexible to increase the flexibility of the cable.

We use patch-cord to communicate with the vehicle and video streaming.

We stretched cable silicone tube for protection against mechanical damage and sealing. Basing on experience of last year, we have stretched into the hose first steel cable, and then linking it to the wire, pulled them. Since last year there was a lot of space in the cable, we decided to reduce the inner diameter and bought a silicone tube with an internal diameter of 10 mm (instead of 16 mm). Tether occupied all the available space in the tube, so the work with the cable taken a lot of time and effort.

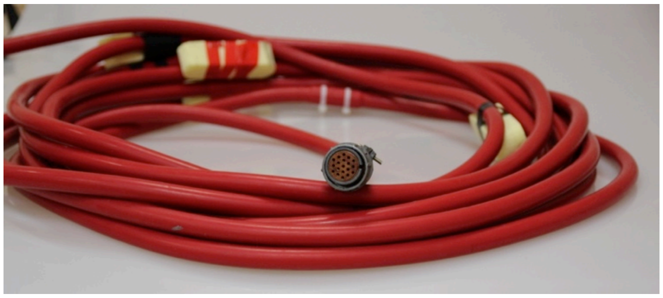


Fig. 9. Tether

Surface equipment

Surface equipment consists of a control unit, joystick, and additional laptop. The control unit - a challenge for our company. This device combines the functions of a TV, a full-fledged computer and switching unit (device, which have a power supply for training and distribute video signal). In the matrix, the built in case, we display video from a rotating camera, and laptop displays video from two extra cameras. To connect the matrix we used board scaler. There is installed pilot program on the desktop computer control unit, which displays readings from the sensors, the list of the mission tasks, video from rotating camera and timer.

Also, the control unit includes voltmeter and ammeter. There is established relays for easy turning on the unit: ROV can be powered both with our source or competitive. Also drawing on the experience of last year, there was decision to establish 2RMGD connector from the side, so that the cable doesn't bent and doesn't disturb the pilot.

To run all the components of the control unit and the vehicle, you should consistently press the 3 switches on the dashboard: Orange includes electronics on the surface, blue turn on the computer, and the red power submits to the vehicle.

To ensure the safety of equipment and people , we use fuse on 25A .This value was calculated from this formula:Overcurrent Protection = ROV Full Load Current * 150% , it provided by the organizers of the competition.

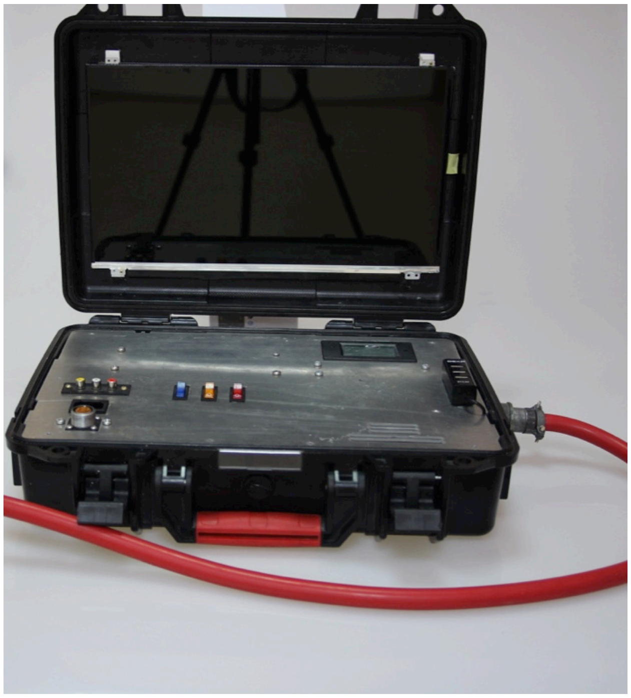


Рис. 10. Control unit

Payload tools

Main manipulator

We had decided to use last years manipulator because it was suitable for the accomplishment of the most missions of this year. Of course, we wanted to manufacture our own two degrees of freedom manipulator, but yet we had to confess that we had a lack of knowledge to design it.

Bottom grabber

We use the bottom grabber for the accomplishment of some tasks. With its help it's possible to execute the raise of the satellite, samples of petroleum and coralls, and, in addition, to connect with ESP. The device is easy to create and use because it's a metallic capture from some construction with a servomotor. But there appeared a problem with the hermetization of the servomotor. At first, we tried to solve it by using sealant and gaskets. All the places of the attachment we covered with sealant and two gaskets were inserted on the axle: the lower one covered the chinks while the upper one pressed down for the most security. However, it didn't help and we, thus, burnt two servomotors. Then we realised that we had been doing something wrong, rethought the task and decided to just cover the control card with electrically insulating varnish and not to hermetize the body frame. And it worked.

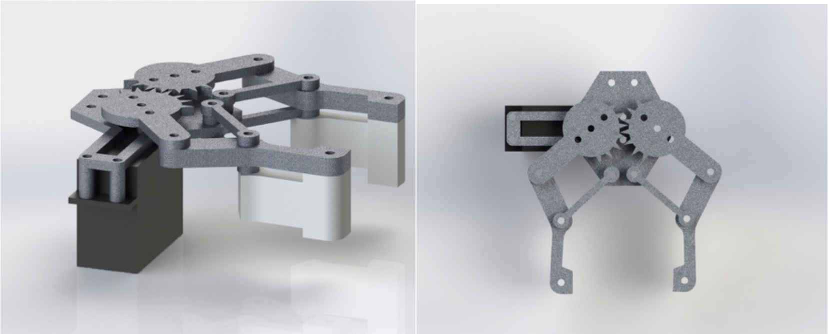


Fig. 11. Model of bottom grabber

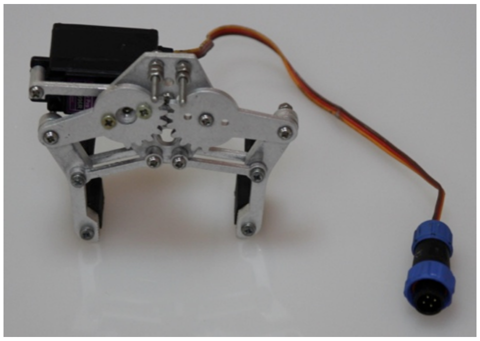


Fig. 12. Bottom grabber

Temperature sensor

One of the tasks of the mission is to measure the water flow temperature. For the maximum number of points we have made a temperature sensor. The ROV leaves the temperature sensor in the stream of water and swims to perform other tasks. The temperature sensor is made of a metal tube with a radius of 20mm(former desoldering pump) sealed with plugs . Inside the housing is placed a DS-18b20 sensor, a Arduino mini pro (5v, 16 m / Hz) controller, and for processing and transmission of information to the surface we use the RS-485 interface. So the sensor does not pop up, we strung lead directly to the sensor cable.

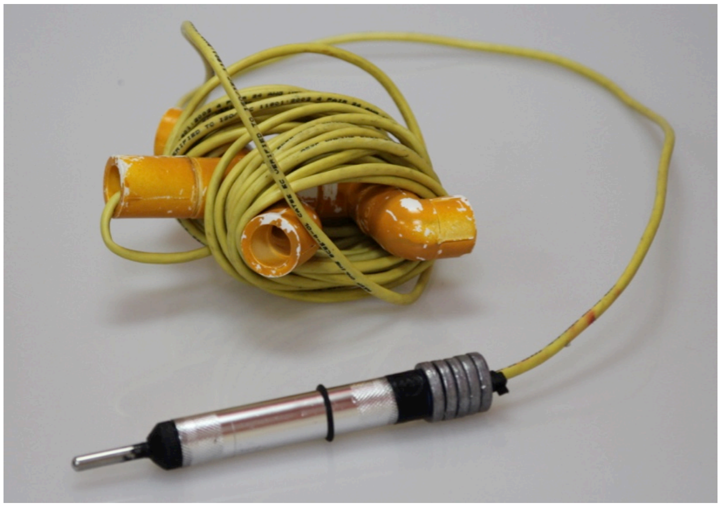


Fig. 13. Temperature sensor

Software

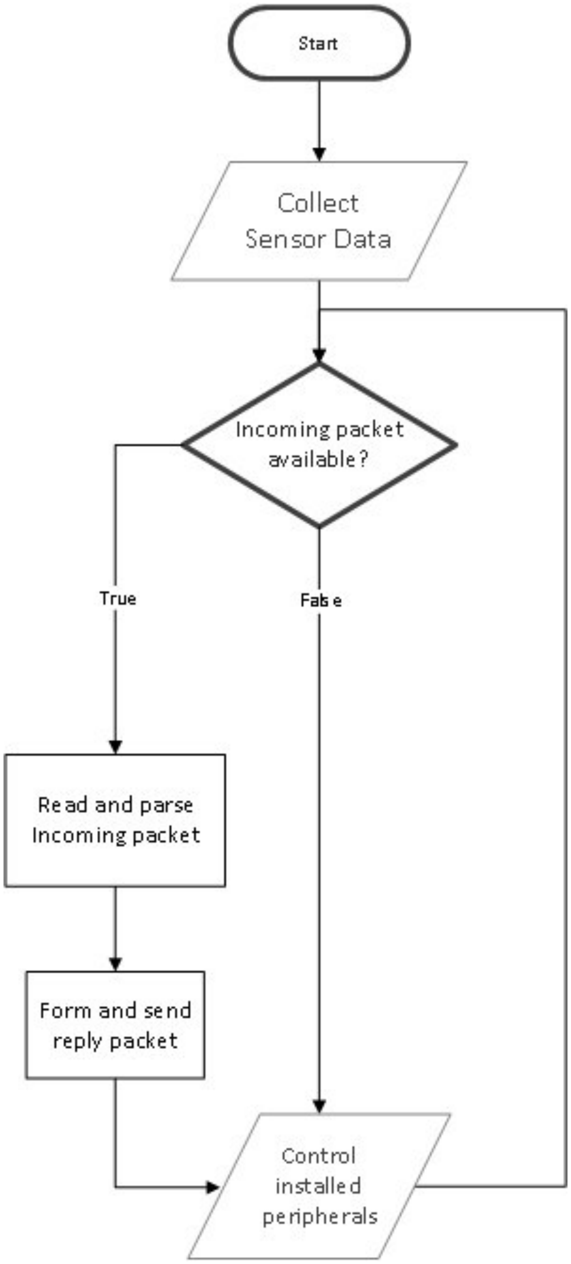

Start
Collect Sensor Data
Incoming packet available?
True
False
Read and parse Incoming packet
Form and send reply packet
Control installed peripherals

Fig. 14. Flow-chart of on-board software

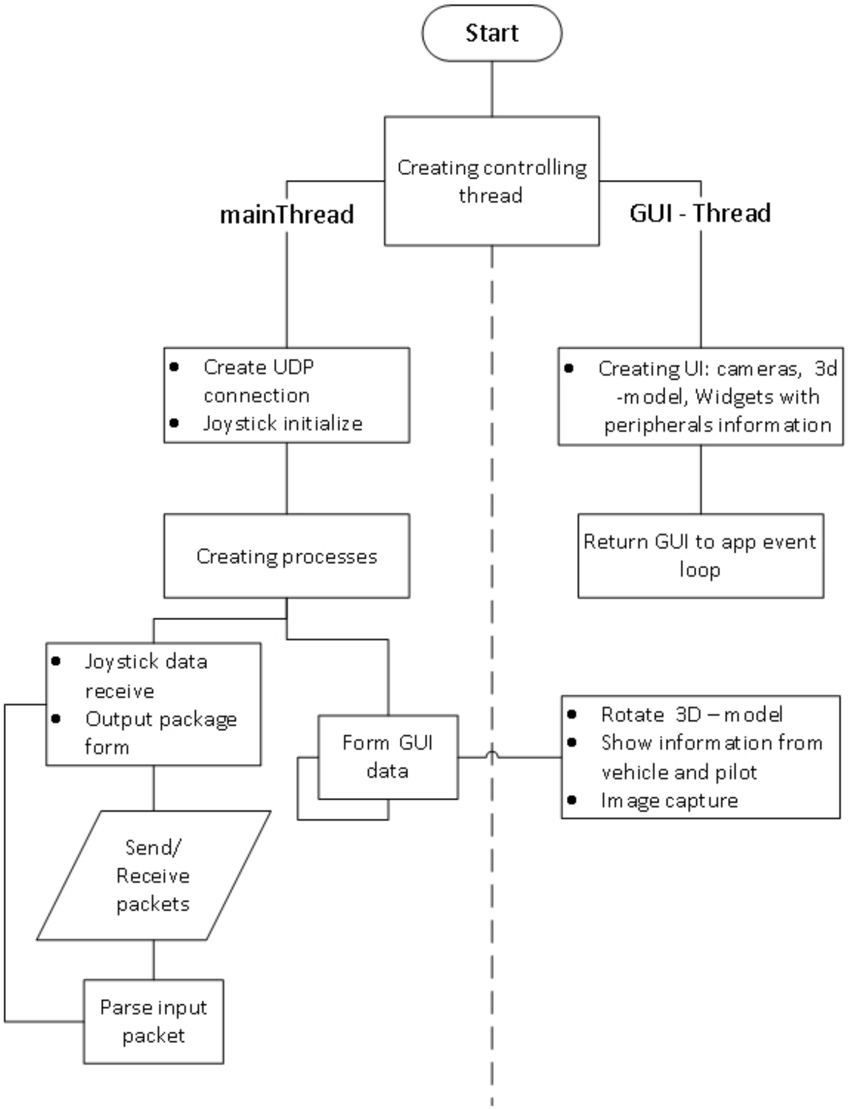

Start
Creating controlling thread
mainThread
GUI - Thread
Create UDP connection
Joystick initialize
Creating UI: cameras, 3d -model, Widgets with peripherals information
Creating processes
Return GUI to app event loop
Joystick data receive
Output package form
Form GUI data
Rotate 3D – model
Show information from vehicle and pilot
Image capture
Send/ Receive packets
Parse input packet

Fig. 15. Flow-chart of pilots software

Pilots software

Before beginning the pilots software development, we analyzed the mistakes of last year's program, our new ideas and requirements in this year. One of our main innovations in this year is the division of the controller program into applications of the first and second pilots for more effective mission passage. The first pilot program is installed on the control unit and second is on a laptop.

The first operator program's screen displays the information needed to successfully pass the mission: video from cameras, data from the navigation sensor, the current mission and auto control modes status. Assistant's interface shows data for planning the following actions: the list of missions, the remaining time and the video from cameras. It allows the first operator to concentrate on current mission passage, and the second pilot to create more effective strategy of mission passage.

For controller development we chose a cross platform framework Qt, because of its conveniences in GUI creation, and our experience with it.

You can notice that the algorithm is processing in two different threads. We did it for stable work of the GUI thread. Communication between threads is done by the SIGNAL/SLOT technology provided by QT.

On-board software

On-board software was written using Arduino IDE. For simplify software debugging, we used TFTP BootLoader which allows us to upload software via an Ethernet cable. That greatly simplifies working with the Arduino as there is no need to open the electronics unit.

Software controls all playload installed on the vehicle (propulsion system, tighten/loosen manipulators, polling and filtering sensors values). Software calculates and controlls motors thrust based on sensor and joystick values and statuses of auto-depth, auto-pitch and auto-yaw. For safety purposes, when the ROV has no incoming packages for 5 seconds, all thrusters automatically switch off. So if there are any problems with the tether and/or a connection loss, chances of mechanical damage are much smaller.

Challenges

Technical

In this year one of the general challenges in the development of the vehicle was using Beagle Bone Black (BBB), as the main on-board computer, and the subsequent failure of his side Arduino Uno. We spent a lot of time and resources to develop the software and electronics for working with the BBB. Cause of inexperience in dealing with such complex electronic devices a lot of the failure of the BBB in April, we were forced to replace the BBB to the Arduino Uno. After a large processing on-board electronics and software development for the new platform there was result in 2 weeks.

Non-technical

This year most of last year company’s members participates in the competition in Ranger class for the last time. Therefore, the company had a task to develop not only the vehicle, but also to convey last year’s experience, to the newly arrived employees. it was very important to show the basics for beginners of how to work properly as a team and explain them the process of developing an ROV. We were able to cope with this problem by using a system of mentoring. Each newcomer was attached to an experienced employee. And the experience of transfer consists of 4 stages: "I say, I do", "you say, I do", "I say, you do" and "you say, you do."

This allowed us to train new team members to participate in future competitions and develop their skills in teaching others.

Troubleshooting Techniques

To eliminate errors in the on-board firmware a debug mode was made. During its work all the data required for debugging is sent written to the serial port: the values of variables, function entry and exit time. This data allows us to determine in which part of the program an error occurs and what happens prior to it. Analysis of this data allows us to identify the cause of the error and correct it.

Future Improvements

We have an objective to make in the next year's ROV's design elements from composite materials to reduce the weight of the vehicle, while not losing the strength of the frame, and so it doesn't depend on the capabilities of the waterjet cutting.

We plan to make our own controller board and motors drivers.

We also plan to develop our own thrusters with magnetic coupling instead of a cuff.

Lessons Learned

Technical

The main technical lesson for our company was the conclusion that we made after an error with the BBB. We understand that before choosing the main on-board device, you must familiarize yourself with all its specifications, and it is very important to constantly check the operation of all the equipment together, to integrate the work of all employees, as the absence of this may lead to incorrect operation of the assembled device.

Interpersonal

During the team work on the machine an enormous number of interpersonal lessons was made. Everyone makes mistakes sometimes, and our company is no exception. CEO Anton Konstantinov helped newcomers realize and mend their mistakes. The newcomers didn't expect such rigorness from the captain. But this rigorness in the organization of work, in discipline, to the purity of the workplace and to other aspects of team work has helped us, novices, to grasp, to experience and understand how to work on a "real" project.

Reflection

Joint

While working on the ROV, all employees improved their skills in three areas of engineering: mechanics, electronics and programming. And also our company has become even more cohesive than it was before. We've all endured many new lessons and did work on last year's mistakes. It is unlikely that we would be able to get this kind

Herman

This year I learned a quaternion stabilization algorithm of Euler angles for processing of raw values from the navigation sensor, I learned how to use streams and more. When working with Beagle Bone Black I improved my skills in Bash, learned the Python programming language. But most importantly, these skills and knowledge are needed by the company and will be useful to me in my future career.

Anton Lobov

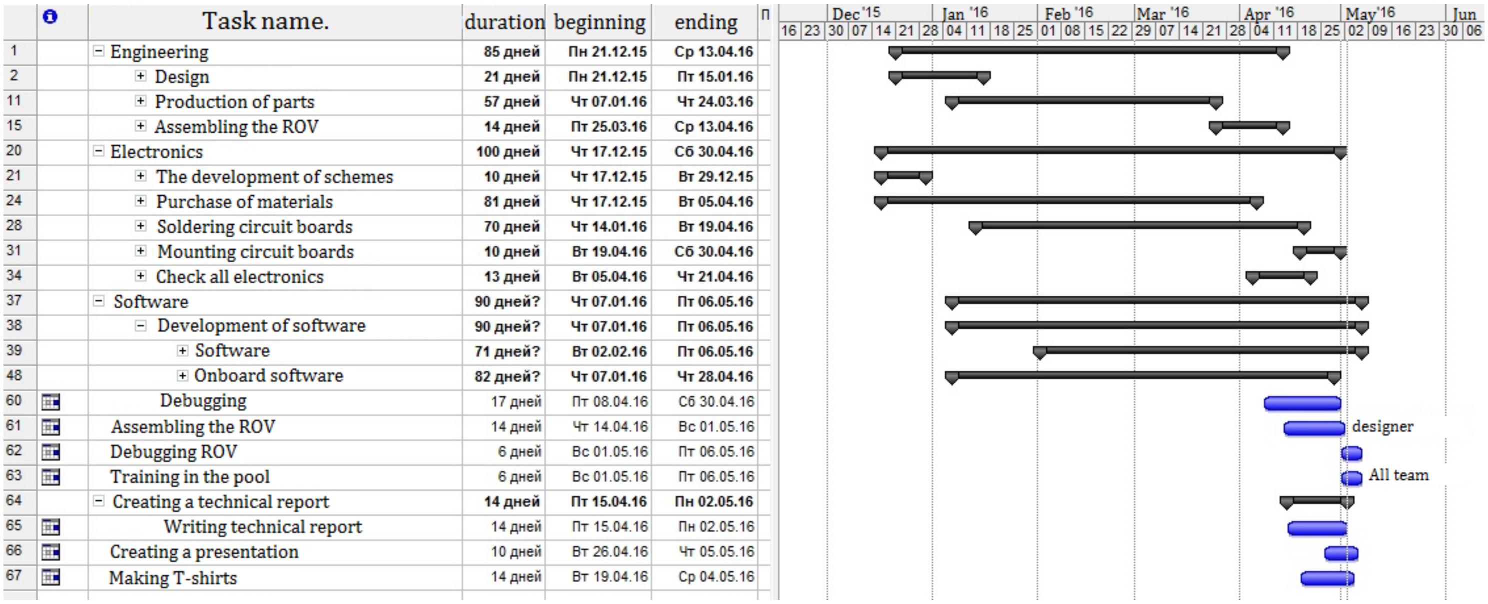
I chose electronics because I'm interested in this area, and I can ask my father, a radio engineer, about any electrical problems. During the work on the ROV, I learned how to solder, how to make circuit boards, how to repair appliances, how to work with a drill, Dremel and, most importantly, how to work in a team. I got a huge, invaluable experience and I am sure that I will continue to engage in underwater robotics in the next year.

Ignat

I am very glad that I was in the underwater robotics team, as this work in a complex, interesting and unusual environment, which requires great responsibility and discipline. I chose the field of electronics, because I'm interested it. While working on the ROV, I studied various board manufacturing technologies, learned to repair various electronic devices, worked with many useful tools. I got a great experience, and I want to continue to work with the company next year.

Project Management and Teamwork

Our company consists of 9 people, we all have different technical and communication levels. Many members were in last year’s team, so there was a constant exchange of experience among the team members. To organize the work effectively, first of all we devided into three working groups: electronics engineers, programmers and designers. Each group appointed a senior, who was responsible for the distribution of work within their team and for compliance deadlines. The terms were defiened after we had jointly conducted a decomposition of the problems and the captain has developed a detailed work plan using a Gantt chart.



	ℹ	Task name.	duration	beginning	ending
1		⊟ Engineering	85 дней	Пн 21.12.15	Ср 13.04.16
2		⊞ Design	21 дней	Пн 21.12.15	Пт 15.01.16
11		⊞ Production of parts	57 дней	Чт 07.01.16	Чт 24.03.16
15		⊞ Assembling the ROV	14 дней	Пт 25.03.16	Ср 13.04.16
20		⊟ Electronics	100 дней	Чт 17.12.15	Сб 30.04.16
21		⊞ The development of schemes	10 дней	Чт 17.12.15	Вт 29.12.15
24		⊞ Purchase of materials	81 дней	Чт 17.12.15	Вт 05.04.16
28		⊞ Soldering circuit boards	70 дней	Чт 14.01.16	Вт 19.04.16
31		⊞ Mounting circuit boards	10 дней	Вт 19.04.16	Сб 30.04.16
34		⊞ Check all electronics	13 дней	Вт 05.04.16	Чт 21.04.16
37		⊟ Software	90 дней?	Чт 07.01.16	Пт 06.05.16
38		⊟ Development of software	90 дней?	Чт 07.01.16	Пт 06.05.16
39		⊞ Software	71 дней?	Вт 02.02.16	Пт 06.05.16
48		⊞ Onboard software	82 дней?	Чт 07.01.16	Чт 28.04.16
60	▦	Debugging	17 дней	Пт 08.04.16	Сб 30.04.16
61	▦	Assembling the ROV	14 дней	Чт 14.04.16	Вс 01.05.16
62	▦	Debugging ROV	6 дней	Вс 01.05.16	Пт 06.05.16
63	▦	Training in the pool	6 дней	Вс 01.05.16	Пт 06.05.16
64		⊟ Creating a technical report	14 дней	Пт 15.04.16	Пн 02.05.16
65	▦	Writing technical report	14 дней	Пт 15.04.16	Пн 02.05.16
66	▦	Creating a presentation	10 дней	Вт 26.04.16	Чт 05.05.16
67	▦	Making T-shirts	14 дней	Вт 19.04.16	Ср 04.05.16

Fig. 16. Gantt chart

We were meeting two times a week during the design phase. During manufacturing the number of meetings increased to 4 times a week. And during training in the pool we worked every day in two shifts, almost aroun-the-clock. To track the progress and organization of the training process, we developed a training protocol, in which we recorded the results of attempts.

Also, throughout the project, we had a once a week meeting with our mentors(on Thursday at 16:00), we told them about the results of the week's work and shared our plans for the next 7 days.

For communication efficancy between employees, we used a group in WhatsApp and VKontakte.com. This allowed us to quickly share documents and photos, to solve technical and organizational issues.

For co-writing a technical documentation, we used Google Docs.

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We would like to thank the MATE Center for the opportunity to participate in these competitions. You are doing a great job on a planetary scale.

We express our gratitude to the Maritime State University. n.a. adm. G.I. Nevelskoy for being allowed to train in the pool for free.

Also thanks to our friend Ekaterina Tikhomirova, winner in the Olympiad of Russian language, for the spell check in our technical report.

And, of course, we would like to thank our parents, who have supported us throughout the project. You understood our late night returns to home, malnutrition and the high cost of a taxi. Thank you very much.

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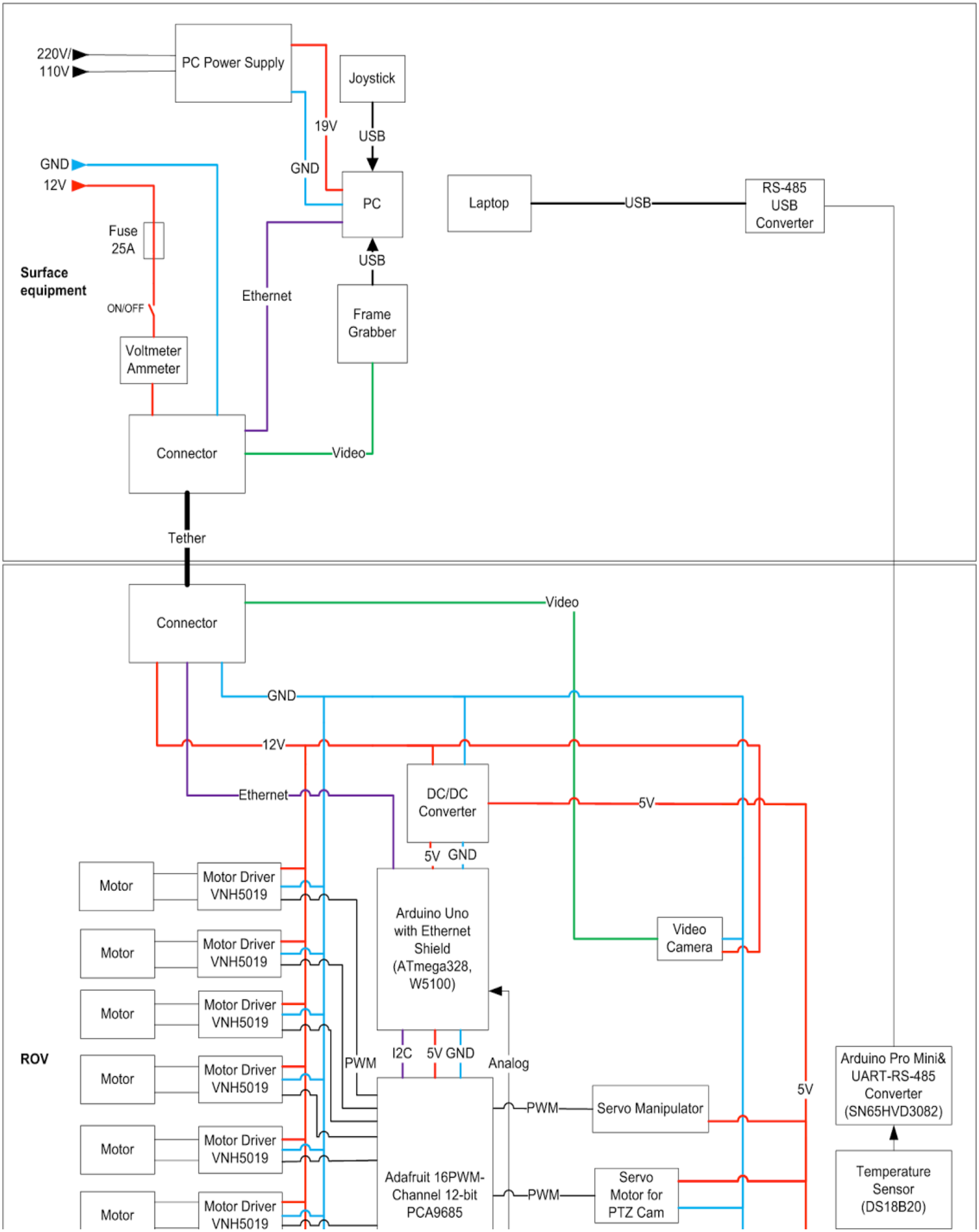
И БЫТОВОЙ ТЕХНИКИ

1890

ЦЕНТР РАЗВИТИЯ
РОБОТОТЕХНИКИ

Appendix 1. SID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110V
PC Power Supply
Joystick
19V
USB
GND
PC
Laptop
USB
RS-485
USB
Converter
GND
12V
Fuse
25A
Surface
equipment
ON/OFF
Ethernet
USB
Frame
Grabber
Voltmeter
Ammeter
Connector
Video
Tether
Connector
Video
GND
12V
Ethernet
DC/DC
Converter
5V
5V GND
Motor
Motor Driver
VNH5019
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W5100)
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Camera
ROV
PWM
I2C
5V GND
Analog
PWM
Servo Manipulator
5V
Arduino Pro Mini&
UART-RS-485
Converter
(SN65HVD3082)
Adafruit 16PWM-
Channel 12-bit
PCA9685
PWM
Servo
Motor for
PTZ Cam
Temperature
Sensor
(DS18B20)