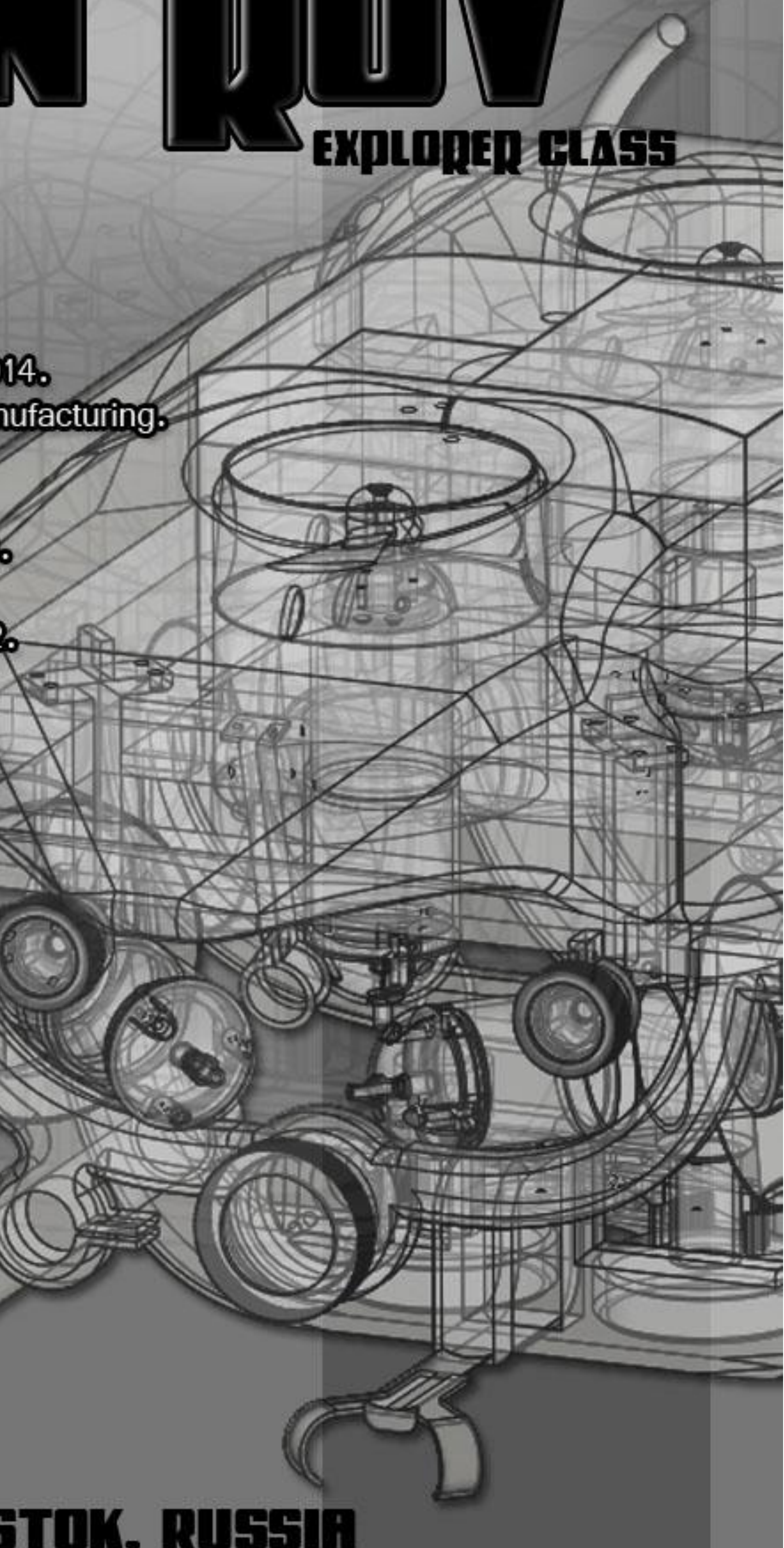
FAR EASTERN FEDERAL UNIVERSITY

2012 MATE INTERNATIONAL ROV COMPETITION

PRIMORYE COAST'S PROJECT:

ALIEN ROV

EXPLORER CLASS



COMPANY MEMBERS

Andrey Sakharov. Graduation: 2014.
CEO, Lead Programmer, Pilot.

Angelina Borovskaya. Graduation: 2014.
Head of CADD, Art designer, Manufacturing.

Anton Shiryaev. Graduation: 2012.
Props constructor, CFO.

Anton Tolstonogov. Graduation: 2013.
Programmer, Props constructor.

Dmitry Tregubenko. Graduation: 2012.
Constructor.

Maxim Fursov. Graduation: 2013.
Payload tools constructor, R&D

Roman Babaev. Graduation: 2012.
Electronics, Head of Test&Debug.

Vladislav Bolotov. Graduation: 2016.
Programmer, Media.

Yroslav Volkov. Graduation: 2013.
Electronics.

MENTORS

Sergey Mun
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Vladimir Kostenko
Igor Tuphanov
Igor Pushkarev

VLADIVOSTOK, RUSSIA

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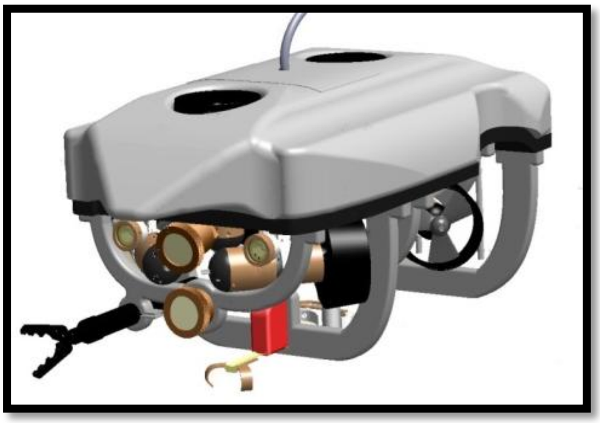

Fig.1 Alien ROV

ABSTRACT

The "Primorye Coast" company (Fig.2) is proudly presents "ALIEN ROV" (Fig. 1), that was designed specially to accomplish the mission, proposed by the customer, MATE Center.

Our vehicle has a specific structure. It was designed on the principles of bionics. ROV has six powerful thrusters that can provide steady position while working with variety of devices or making video capture with four cameras. In addition, special payload installed on the vehicle: a tank flushing device, a measuring tape for the determination of the ship's length, a metal detector to search for the debris of the vessel, a holder for the magnetic patches and a manipulator for attaching the lift bag to the mast and transplanting corals.

Total expense for the development of the vehicle is $ 10,420.

During the design and development process, team members got vast experience in both technical and interpersonal spheres.

Fig. 2 "Primorye Coast" company

Standing (left to right): Yaroslav Volkov, Roman Babaev, Angelina Borovskaya, Anton Tolstonogov, Andrey Sakharov, Maxim Fursov

Sitting (left to right): Sergey Mun, Anton Shiryaev

BUDGET

"Money isn't everything"

EXPENDITURES	
Item	**Amount, $USD**
Manipulator	3500.00
Motors (6 x $610)	3660.00
Propellers (6 x $60)	360.00
Cameras (4 x $154)	616.00
Electronics	970.00
Pressure sensors (2 x 43)	86.00
Pelican case	377.00
Prop construction	300.00
Tether	167.00
Mounts	134.00
Payload tools (materials)	250.00
Visa, air tickets, cost of living, MATE fee	26377.00
Team shirts	240.00
TOTAL	**37037.00**

DONATIONS		
Item	**Source**	**Amount, $USD**
Laptop	Business Incubator of FEFU	866
Pressure housings	Centre for Advanced Technologies of FEFU	2000
Polyurethane foam	Institute for Marine Technology Problem	230
TOTAL		**3096**

CONTRIBUTIONS	
Item	**Amount, $USD**
FEFU	32807
Office for Youth of Vladivostok city	3000
Student contributions	1230
Donated materials	3096
TOTAL	**40133**

The total project cost, taking into account the materials and the cost of travel is $40133.

FRAME

Vehicle's design was made in Solid Works 3D CAD. Visual 3D models allow all team members to understand how the ROV will look like and how it will function.

The basis of the vehicle's design is the frame (Fig. 3). It was designed on the principles of bionics, and therefore resembles the skeleton of marine animal. The frame is made of polypropylene. We chose polypropylene because of its durability and because its density is less than the density of water - it grants ROV additional buoyancy. The frame consists of an upper plate with the majority of devices attached to it and five "ribs" required for the payload installation.

Fig.3 Frame and buoyancy

There is a buoyancy made of polyurethane foam mounted on top of the upper plate. The shape of buoyancy is noteworthy. For cutting the buoyancy from polyurethane foam and making the necessary forms we used the "burning hot string" with flowing DC of 4A. With such "strings" we can neatly cut the foam like butter.

Fig. 4 "Burning hot string"

PROPULSION SYSTEM

The ALIEN ROV has 6 thrusters. Four horizontal thrusters located at 45 degrees to the longitudinal and transversal axis of the vehicle, provide movement and stabilization in horizontal plane: lag, run and course. The horizontal thrusters are attached with special clamps to the upper plate of the frame that has special openings for the clamps. These clamps were designed in Solid Works, and, as well as the frame, made of polypropylene.

Two vertical thrusters provide movement and stabilizations of depth and pitch. We have provided built-in clamps in the upper plate of the frame for mounting vertical thrusters.

HOUSINGS

Containers for the electronic components designed to withstand the pressure at a depth of 6 meters. Housings are made of aluminum. We used the O-rings for sealing the containers. Electronic unit container is noteworthy. It is a complex, but at the same time, the logical structure. The container consists of a cylindrical housing, the chassis to host the electronics boards and two caps (Fig. 5). The top cap is used for input tether and output wires to the thrusters. The bottom cap has output for the wires from the cameras, lights, manipulator, pressure sensor and metal-detector.

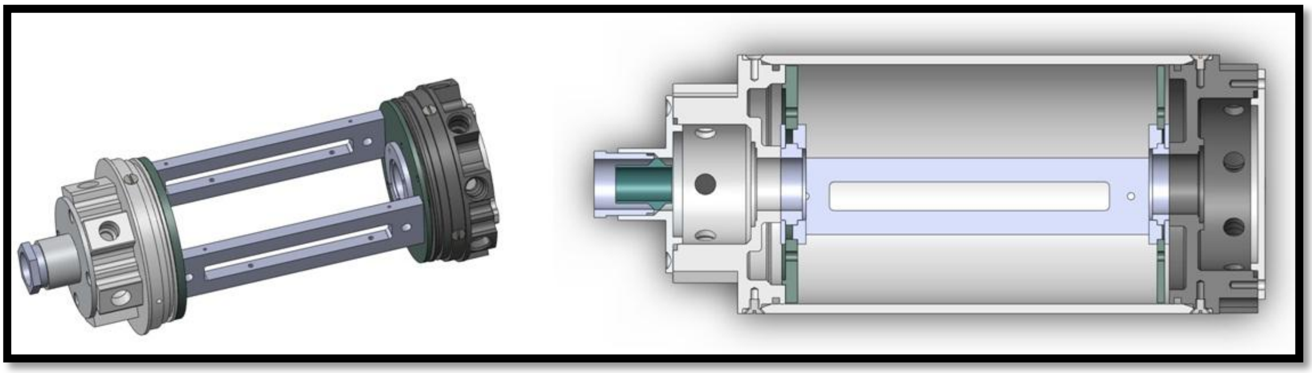

Fig.5 Electronic unit container

SAFETY FEATURES

Safety is very important for "Primorye Coast" company. We have safety features in our vehicle and safety rules that every member of our team must follow.

Our ROV's safety features include:

- thermo sensors in thrusters;
- leak sensors in cameras and electronic unit container;
- electric fuse;
- kill switch for emergency power off;
- shrouded propellers to prevent injury;
- warning signs ;

Safety rules consist of two parts. First part regulates safety during constructing and maintaining the vehicle. Second part establishes rules for deployment, operating and transporting "ALIEN ROV".

"The mediator between head and hands must be the heart"
Metropolis

ELECTRONIC UNIT

The main part of the vehicle's electronic is an electronic unit. Like a human heart it drives all other units and systems to precisely perform the orders of the pilot.

Control signals to the electronics components are passed through the controller board, based on microcontroller TE-STM32F207. It controls pressure sensors (ASDX015A24R-DO, DMP 331 110-999), an electronic compass (HMC6352), a CRS accelerometer, manipulator control board and moreover it controls voltage to the decoder of a multiplexer.

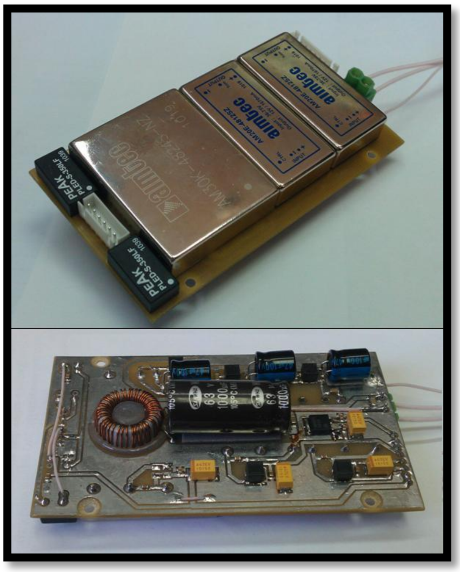

Fig. 6 Power board

Video multiplexer receives signals from the four available cameras to transfer all video streams to the surface where demultiplexer provide desired video stream to the operator's monitor.

Power board (Fig. 6) supplies all the electronics components with necessary voltage (24V, 12V, 5V). Also the microcontroller board supplies 3.3V that is necessary for some components.

CAMERAS AND LIGHTS

We use modular color cameras VM32HQ-B36. Our choice is due to their small size, ease of installation, high sensitivity (0.1 lx) and availability. Among the other advantages of the camera is backlight compensation, useful for underwater observing, because the observed objects will be placed on a background of bright light.

The basis of lights is a torch "Photon" MR-0209 which has nine LEDs in waterproof housing. A container for batteries has been removed as unnecessary, since the lights are connected to the control board power supply. On / off modes is switched through the controller board.

THRUSTERS

Thruster (Fig. 7) consists of motor, propeller and thruster control units (TCUs).

We are using Faulhaber 4490 H 048BS-K312 motors. Our decision justified by such good characteristics as the absence of magnetic losses, low power consumption and compact size. Engine power is also great - it's 212W at 10000 rpm.

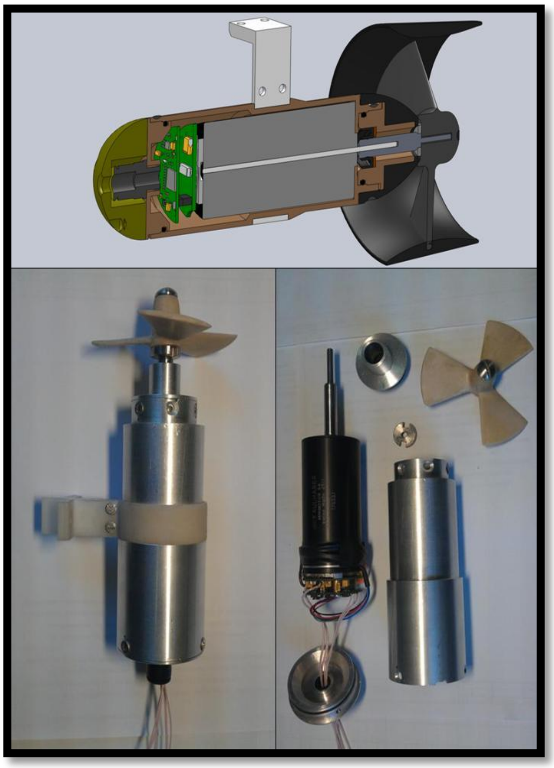

Fig.7 Thruster

We designed propellers ourselves especially for these motors. They were made of plastic using a 3D printer.

There is an integrated TCU in the housing of each thruster. TCUs and the control board are communicating via CAN interface on global bus. In addition we are monitoring current consumption and temperature to prevent overcurrent and overheat.

TETHER

Data cable is designed to transmit signals between electronics unit and the block of switching. For video transmission, we use two 1.5mm coaxial cables with impedance of 75 ohms. The ROV requires rather high power, so we have chosen to use two 6mm power cables. To transmit control signals, we use a twisted pair cable.

To collect all the wires in one tether, we bought a rubber garden hose which was used as a sheath. Broaching wire in the hose is a very laborious, but exciting work. For example, we ended the process of broaching at the top of a five-story building. We stretched the tether to the entire height of the building and straightened all the wires inside. Finally, we got the neat, flexible and durable tether.

COMMUTATION UNIT

Commutation unit is used to separate tether into different lines: power, control and video.

48V from power supply comes to the commutation unit through the fuse, which protects the circuit against excess current. Then the power is supplied to the board of power switches and after that to the ROV.

The video signal passes through the video modulator and then appears as a part of GUI on the laptop screen. Control signals are transmitted between the operator console on the surface and the electronic unit onboard via an Ethernet interface.

An AC/DC converter was integrated to the commutation unit to power the vehicle from the AC power.

CONTROL SYSTEM

We have decided to create a new control system from scratch to provide a pilot with a convenient tool to operate the vehicle in consideration of this year missions. Leading software engineer of our team was guiding novices through the process of the development.

Our workflow was initially planned so that we should concentrate mainly on the developing of ROV's firmware because it was completely new challenge for the team's programmers.

SOFTWARE

"The best things in life are free"
American proverb

Goals and Solutions

There are several goals that we wanted to achieve.

First of all, control board should provide an effective solution for completing this year missions. It should give a pilot all the abilities that he need to smoothly operate the vehicle and help him to get all the tasks perfectly done. But the development of the control system shouldn't take much time because there is a lot of work with on-board firmware to do.

Another point is our intention to use open source software. We would like to use the most up-to-date open-source development tools and free operating system, so we are building our control board on Ubuntu OS using Qt Source Development Kit and open source libraries. This action requires additional attention to prevent the last year problem with incompatible hardware drivers. So, we have taken it into account and upgraded our hardware to a new level of quality and flexibility. Now all communications with the ROV are made through the Ethernet interface that is definitely compatible with Linux OS. Also Ethernet is the most appropriate solution with the best combination of reliability, quality, speed and availability.

Control board's GUI

Our GUI has modular structure. Modularity allows us to vary appearance and split the whole programming task in small problems. Each developer has worked out only his own problems to reduce a number of conflicting code changes. It is mean that they could progress simultaneously. Developed widgets can be easily used in other projects, both by us and other developers (because all the source code is publicly available). Another advantage is that widgets can be separately used for ROV's systems debugging. GUI consists of several widgets: depth, roll-pitch, joystick, manipulator control, LEDs, cameras and others. Important information is always clearly visible for the pilot. ROV is controlled mainly by joystick but the pilot can use the keyboard as well. This provides us with an ability to have two pilots working cooperative.

Main window periodically calls functions which provide data exchange between ROV and widgets, and allocates data for next processing.

This GUI is proved to be quite handy and convenient to use during the training sessions.

We provided a possibility to configure TCUs from the surface. That gives us an ability to easily change engine’s parameters without reflashing and therefore to save time. All configurations are saved in structured XML-documents. It's quite visually, informative and handy.

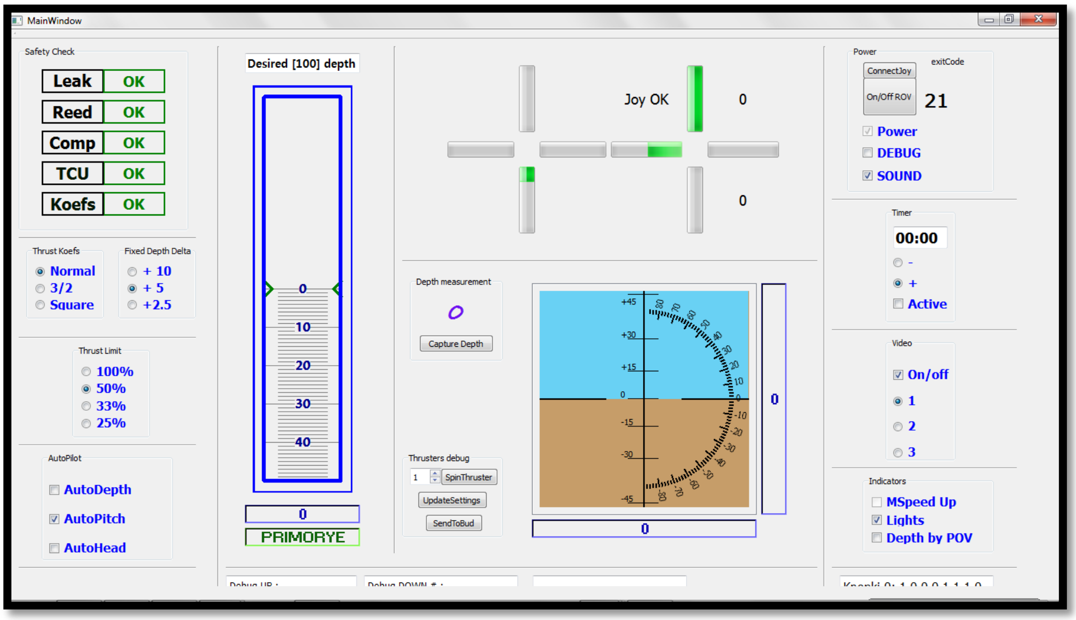

Fig.5 GUI

FIRMWARE

General Description

The brain of the vehicle is a board TE-STM32F207 based on the microcontroller Cortex-M3. Its function is the processing and transfer of data between the electronic components onboard and providing communication with the control unit on the surface. To ensure the most effective interaction of all systems, we are using various interfaces for data transmission onboard: CAN (for thruster control), SPI (for three-axis gyroscope and accelerometer) and I2C (for gathering data from a digital compass and an internal pressure sensor). For communication with the operator console we are using Ethernet. The board is also programmed to serve as an autopilot, solving an important task of stabilizing the vehicle.

The structure of the firmware

To efficiently use the microcontroller resources programmers of our team have created firmware which takes into account all the features of the ROV and the needs of each individual mission of this year competition to complete each task as quickly and efficiently as possible.

Firmware consists of a logically separated parts of program code that perform determined functions (sending packets through the certain protocols, providing PID-stabilization, collecting data from the sensors). They are running pseudo-parallel due to specially configured system of hardware and software interrupts with priorities. Presentation of the firmware as a set of features abstracted from each other can streamline and organize the work of programmers. In addition, this approach proved to be very good for debugging, letting us to make an independent tests of the individual systems for troubleshooting.

PID controller

Successful completion of the missions requires our vehicle to be stable and maintain desired position for a long time. We made an autopilot built on microcontroller allowing us to use autopitch, autohead and autodepth stabilizations. A quiet effective proportional integral derivative (PID) mechanism was implemented for accurate vehicle stabilization. The proportional term produces an output value that is proportional to the difference between desired and current values. The integral term accelerates the movement of the process towards setpoint and corrects statistical error. Derivative control is used to reduce the magnitude of the overshoot produced by the integral component and improve the combined controller-process stability. We paid special attention to configuring the PID controller, because roughly chosen parameters could easily cause a destabilization of the vehicle, which have to be avoided at all costs in order to successfully complete the mission.

PAYLOAD TOOLS

TASK 1

The first task includes an extensive list of sub-tasks: measuring the length of the wreck, the definition of the orientation of the ship, the recognition of metal debris, scanning of the shipwreck with sonar.

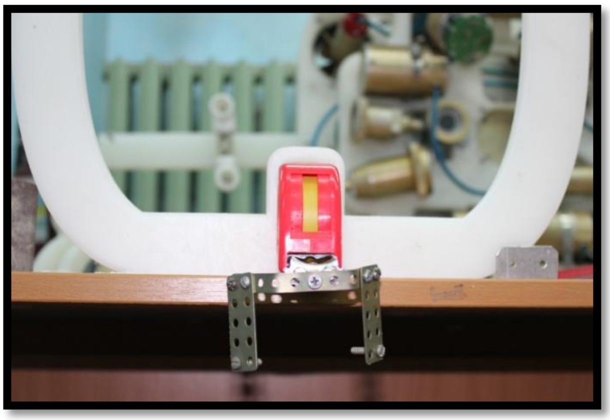

Fig.9 Tape

To measure the length of the wreck we use a five-meter measure tape with a special mount for fixing to the bow of the ship. The tape is located such that the bottom camera allows seeing the current value of the measurement. To accomplish the task we cling to the nose of the ship and moving toward the stern, at the same time tape is unwinding and when ROV reaches the stern we see a total length of the wreck.

We determine the orientation of the vessel by using the electronic compass mounted on the vehicle. When the ROV is parallel to the frame of the ship, the orientation is indicated by the compass. To correctly set the vehicle parallel to the stern of the ship, it is necessary to combine special vertical marks on the operator's monitor with the ship's frame.

To determine metal debris we have developed a metal detector based on the principal of depending inductance of the coil from the magnetic properties of the environment. When approaching the device to the metal the inductance of the coil increases, and therefore decreases the frequency of RC-circuit. These changes are monitored by the microcontroller board. The advantages of this metal detector are compactness, accuracy, and reliability.

Also in the first task we have to simulate the work with the sonar. "Sonar" in this case is the front camera of the ROV. It's required to keep in the monitor an inner ring of the target and two black marks within 10 seconds. To ensure correct execution of this task we use stabilization system based on the PID - controller. This system provides stabilization of pitch, depth and head.

TASK 2

The second task also has several sub-tasks: removing a fallen mast, transplanting corals, measuring by sensors and flushing the fuel tank.

The ROV removes the fallen mast from the shipwreck with the help of lift bag. To attach the lift bag to U-bolt on the mast we use a carbine clamped in the griper of manipulator. The lift bag is inflated with the help of a pump, and after that tether manager transports the mast from the worksite.

The ROV uses a manipulator to remove endangered encrusting corals from the ship's hull and transplant them to a safe place.

To check whether there is fuel in the tank, we need to produce a series of measurements. We use a polypropylene tube 12 cm long and 2 cm in diameter as a sensor.

Fig.10 Tank flushing device

We have made a tank flushing device to penetrate through the in/out holes to safely remove the fuel from the tank. The device consists of two metal tubes, which were fixed on the vehicle, two hoses and surface pump. The tubes have sharp tips for easy penetration through the layer of silicone. Two flexible hoses made of silicone are connected to the top of the tubes. The other ends of hoses are connected to the pump on the surface. When the tubes are inside the fuel tank, the team turns on the pump that pumps seawater into the tank. As a result, the fuel vent through the second tube, because we make a negative pressure inside the second hose. That is how we flush the fuel tank.

There is a safety valve on the outflow hose to prevent leakage of fuel. After a complete flush we extract the tubes from the tank.

Also after washing the tank must be sealed by special magnetic patches. We have developed a holder for faster installation of the patches. With this device we can place both patches at the same time.

Fig.11 Holder

CHALLENGES

New design of ROV

While developing the vehicle, we have decided to create something new, something not like our previous vehicles or industrial models known to us, but capable to perform mission tasks. This is how we have challenged ourselves.

We began from the search of new concept. All team members, not only constructors, became vehicle designers for a while. Team members have proposed several tens of ideas and sketches (Fig. 12). We had heated discussions. "Will it float at all?", "How would it stand on the ground?", "Should the center of masses really be here?", and other more specialized questions which we was asking each other.

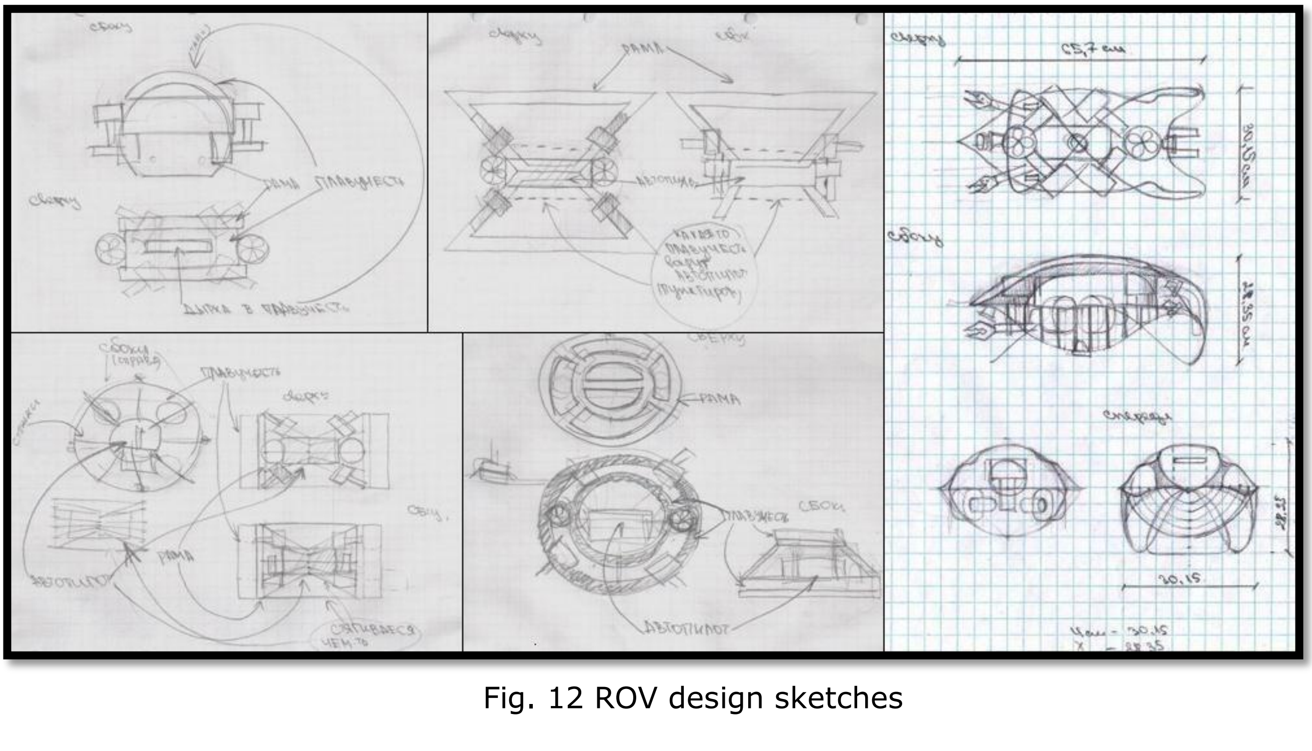

Fig. 12 ROV design sketches

Finally we left two best designs and simulated them with SolidWorks. We chose one of them.

But the most difficult task was ahead: we had to prove to our mentors, that this design, which is not like design of vehicles they used to build, is proper and suits to mission tasks. Our mentors did not accept our design at first. We came to a compromise in details and defended our initial idea after heated discussions.

Extreme teambuilding

"In unity there is strength"
Proverb

For many of our teammates this project was the first experience of teamwork. That was a challenge to us: to unite in short time and an efficient team. So we had to make teambuilding and chosen mountains as a place for that. We have planned three-days-long camping in tents. There was a snow, flood, steep slopes and many other difficulties in the mountains (Fig. 13). But thanks to these we begun to trust each other and felt unity. Out work became more productive after this camping, and our communication became more kind and efficient.

Fig. 13 Mountain teambuilding

TROUBLESHOOTING TECHNIQUES

Video streaming

Last year we have tried to output video on the screen of computer, using video capture card AverMedia DVD EZMaker 7. But Linux driver for this card was using Video4Linux1 interface. This interface is deprecated in current Linux kernel versions, which uses Video4Linux2. We could use older kernel version, but this solution was incompatible with our vehicle controlling program. So, we have denied the idea to show video on the screen of computer last year.

The situation has changed this year. Beta-version of Linux driver for our card was released, but the driver was unstable and we had to change the driver source code ourselves to overcome this. The code was poorly documented and difficult to understand. As a result of few weeks of hard work the driver was fixed and we began to embed video widget in our vehicle controlling program. Our program uses Qt SDK, which has not tools for video streaming. So we have found an alternative solution. We have coded video streaming using Python 2.7 and bound Python widget with Qt/C++ program, using Python Qt. After a few days of work the widget was done.

Burned chip

One day during the usual working process the microcontroller board suddenly stopped to react on external signals for some undefined reason. We have decided that one of the components of the board was broken. We could not establish the exact cause of failure, thus we asked our mentor in electronics.

Under his guidance we began to investigate the problem. During the search of a short circuit suspicion fell on the Ethernet controller Realtek RTL8201BL. For confirmation of the hypothesis we used the following method. When power is supplied, burnt components no longer perform their functions and act like a simple load which heats up: more current - more heat. With the gradual increase of input current and temperature monitoring of the board components, we found that the Ethernet controller was hotter than the others. Once we soldered it out, the board become working again.

The next problem was to find a new Ethernet controller. As it turned out the cost of that chip was only $2, but it wasn't available in our country. We've found out that this chip was often used in old network cards and motherboards. Fortunately, one member of our team works as a sysadmin. He found an old unused motherboard with the required chip, soldered it on our microcontroller board and, finally, everything began to work again.

FUTURE IMPROVEMENT

Embedded RTOS

To maximize the efficiency of usage of microcontroller resources we can use real-time operating system for embedded devices, such as FreeRTOS or ChibiOS/RT, as a base of our firmware. The key advantages are:

- RTOS provides methods for multithreading with thread priorities
- Includes task scheduling
- Kernel calls for semaphore and queue operations.
- Trace support through generic trace macros.
- Very small memory footprint and very fast execution.
- Synchronous and asynchronous I/O with timeout capability
- Hardware Abstraction Layer with support for many various drivers.
- Support for the LwIP and uIP TCP/IP stacks.

RTOS allows getting top performance and provides additional facilities for using microcontroller functional. It allows to create pseudo-parallel tasks and to choose the best schemes of allocating CPU time. RTOS also supports many default data interfaces, and TCP / IP stack. It can significantly facilitate the work of programmers.

Optical fiber

Next year we are planning to use optical fiber to transmit the video. This foreshadows some difficulties, such as high cost and complexity of installation; however, it will be a priceless experience for us. However, the advantages of using the optical fiber are much greater than the disadvantages. Fiber cables have a smaller diameter, higher throughput and less attenuation than the previously used coaxial cable. Thus, we will reduce the overall diameter of tether and improve the quality of video displayed on the operator's display. At the moment, one of our teammates, Roman Babaev, develop an optical modem to implement transmission and reception of signals over fiber. This work will form the basis of his bachelor's dissertation this year.

LESSONS LEARNED

Forced downgrade

"Bird in the hand is better than pie in the sky"

At first we wanted to use a RTOS on our microcontroller. After a few weeks of hard working we managed to execute our first microprogram under the OS.

However, after adding some new functions the program became more complicated and the OS on our controller began to work extremely unstable. We weren't able to recover stability. The core system of our ROV was malfunctioning and the project was on the edge of failure. An alternative solution was proposed - the refusal of the OS and returning to a usual firmware with the well-tuned system of interrupts. This implementation is more complicated, but it was the only way out of this situation.

On this example, we learned a lot. First, we have mastered the basics of programming the OS on the microcontroller. Secondly, we have understood that when our plans fail, it is important to be able to stop in time to find a way out. And sometimes the way is to use not the best, but working version.

Interpersonal

The project gave a lesson of interpersonal interaction to each member of the team. Most of the guys are newcomers in underwater robotics; each of them is from his own field. When we began the project each group worked mostly separately: programmers with programmers, mechanics with mechanics, etc. But when the assembly started, we had numerous problems. It turned out that programmers and constructors do not know exactly what electronic devices are used in the vehicle, because electronics engineers had to change electronic unit during their work. So, constructors had to design new container for electronics unit and programmers had to change microcontroller firmware.

From this case we understood that it is important for working groups to know general development process and stay opened for other groups in interdisciplinary project. ROV is a system and ROV development needs system approach. Every team member is important, every part of work is important. One should have all elements to build a working system.

REFLECTIONS

Andrey Sakharov: Lead programmer and CEO

Programming and leadership. These are the primary problems that I solved this year. Just like last year I was lead programmer of my team. And moreover, I have very important role of the team's captain. And besides challenges with microcontrollers, development of firmware, building GUI and establishing the communications between various hardware, I solved the problem of establishing effective communications between members of my team and coordinating their activity. It was new duties and new experience for me. I acquired knowledge in very unfamiliar fields such as design and electronics. Furthermore, I learned to allocate time wisely, to plan effectively and to lead people to the great goal. It's very important to unite them and make them firmly believe in their possibilities and in the power of the united team.

Roman Babaev: Electronics

It's my first experience of participation in such a big project. I though, working as a team it's a bit burdensome, because you are responsible not only to yourself but also to other members of the team. Now I have a different opinion, because I really loved cooperative work and the team spirit. It's great to get a helping hand from your teammates when you really need it. You can discuss controversial issues with the team and mentors to find the best solution. It's great to be the part of the team. Thanks to this competition, I increased my skills in soldering of electronic components and obtained valuable experience in the design of printed circuit boards in Altium Designer.

Yaroslav Volkov: Electronics

Participation in this kind of project is an absolutely new experience for me. Prior to joining the team I had very vague ideas about the practical side of my specialty. And here was my first time when I took in hands soldering iron and also got burned by it for the first time. I learned how to work with CAD Altium Designer. I have known bitterness of defeat - when something is not working as it should and the joy of victory - when you designed and soldered the device all by yourself and it works as you expected.

Angelina Borovskaya: Head of CADD

For me this was the year of discoveries. Last year I was an art designer in the team. But this year the situation has changed. I discovered the world of construction of ROVs for myself. And the world fascinated me. I invented and drew more than 10 different sketches of the vehicle's design, mastered AutoCAD and Solid Works, designed two appropriate variants of ROV and then made them together with other team members. Cooperative work with other team members and mentors has opened for me the scope of an effective communication. When you do not know what to do or cannot handle with something, you always can get a hint or a really good advice. But the discoveries does not end there, I'm still waiting for many of them to appear during the competition and, of course, the discovery of America it waiting for me too.

Maxim Fursov: Payload tools constructor

I am studying at the University to become a good programmer, but I fond of the development of various gears. Thanks to the MATE ROV Competition, I had the opportunity to realize my potential of the mechanical designer. My role in the team is the developing of payload tools. It is the first time in my life when such a big responsibility is laying on me. I realized that no matter how good the vehicle is, we won't succeed if I don't handle with my task. This experience made me more organized, disciplined and responsible. And I have made considerable progress in the field of mechanics and engineering.

TEAMWORK

In the organization of teamwork is very important planning and distribution of duties. At the beginning of the project, we have constructed a Gantt chart (Fig. 14), which, of course, changed in the process. The diagram allowed us to properly distribute the load of team members, to coordinate our actions and track progress of the project.

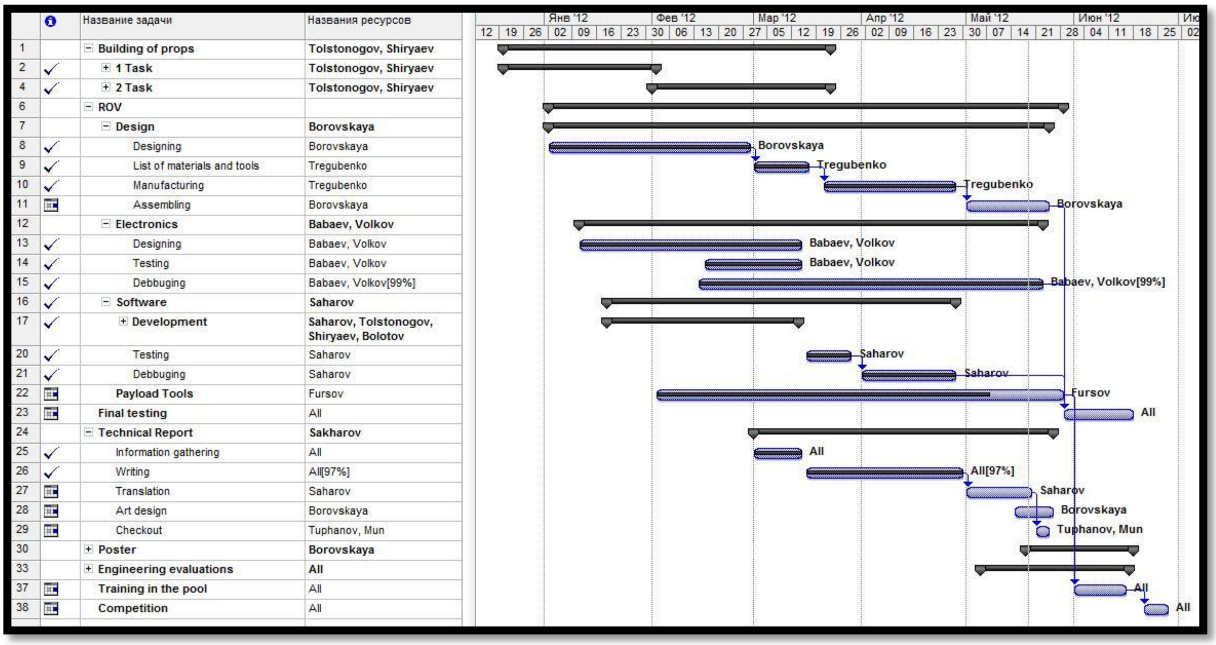

Fig. 14 Gantt chart

Fig. 15 Andrey and Maxim debug control system

Fig. 16 Angelina makes frame

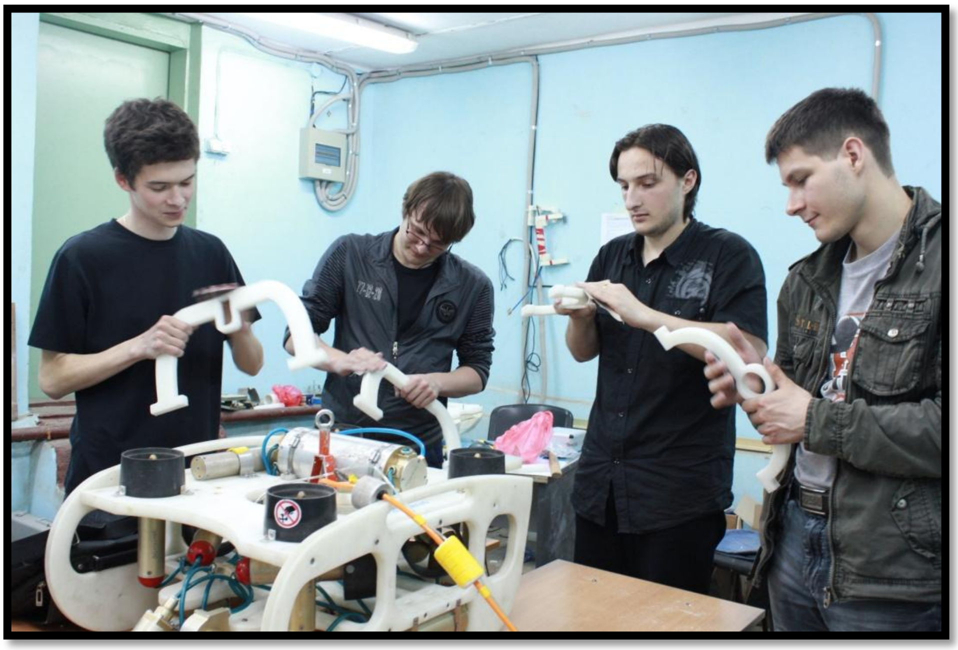

Fig. 17 Yaroslav, Roman, Anton and Anton polish "ribs"

ACKNOWLEDGEMENTS

First of all, we would like to extend our sincere gratitude to the MATE Center for such an exciting event, for helping us by competition materials and resources.

Also we would like to thank:

- Mentors, especially Mun, Sergeenko, Mikhailov, Goy, Shcherbatyuk, Kostenko, who found time in their busy schedule to share with us valuable experience and give us feedback on our work.

- Sponsors: Business Incubator, Center of Advanced Technologies, Department of Youth, Institute of Marine Technology. Without their contributions and financial support we would not be able to build our vehicle.

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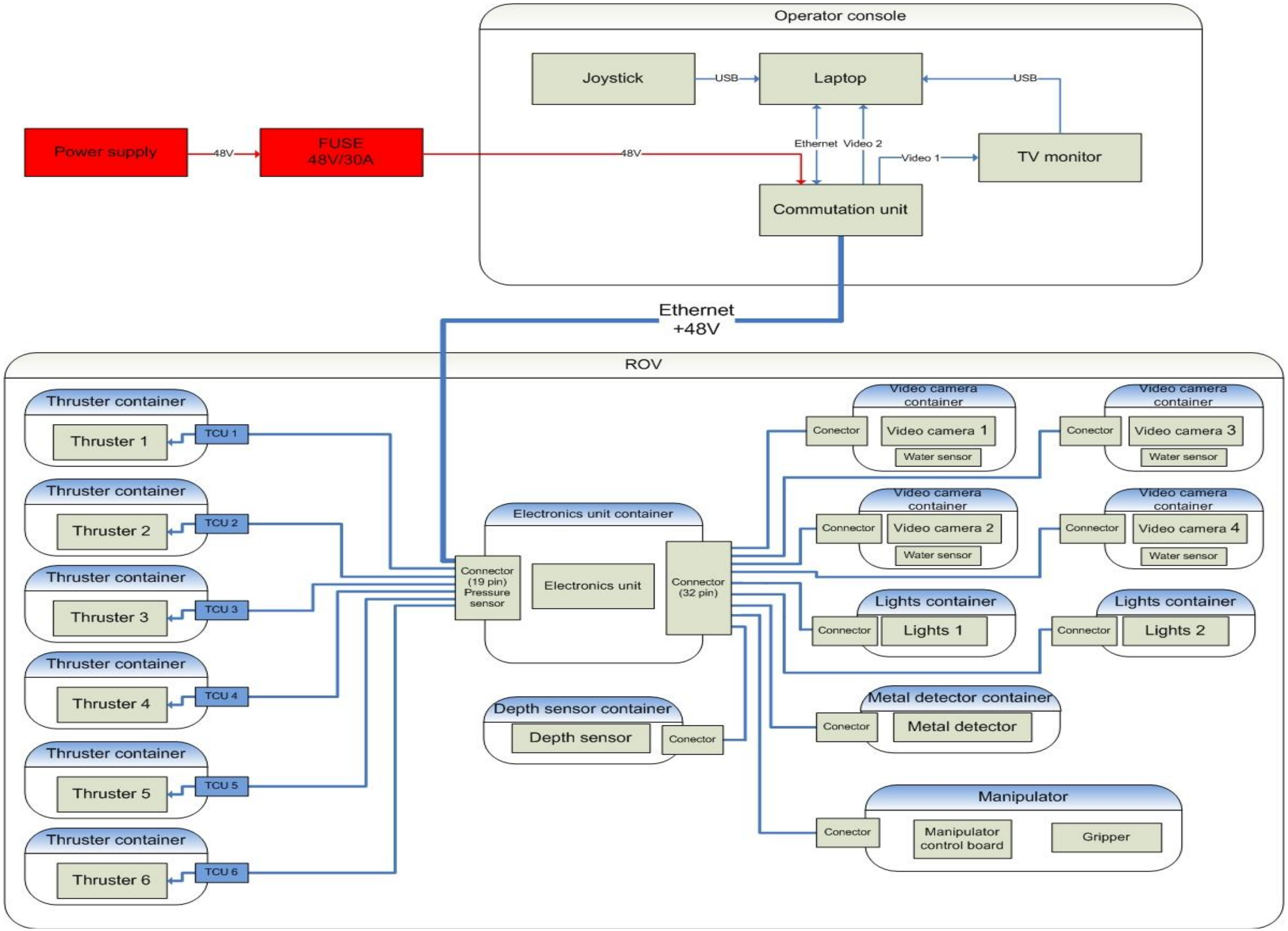
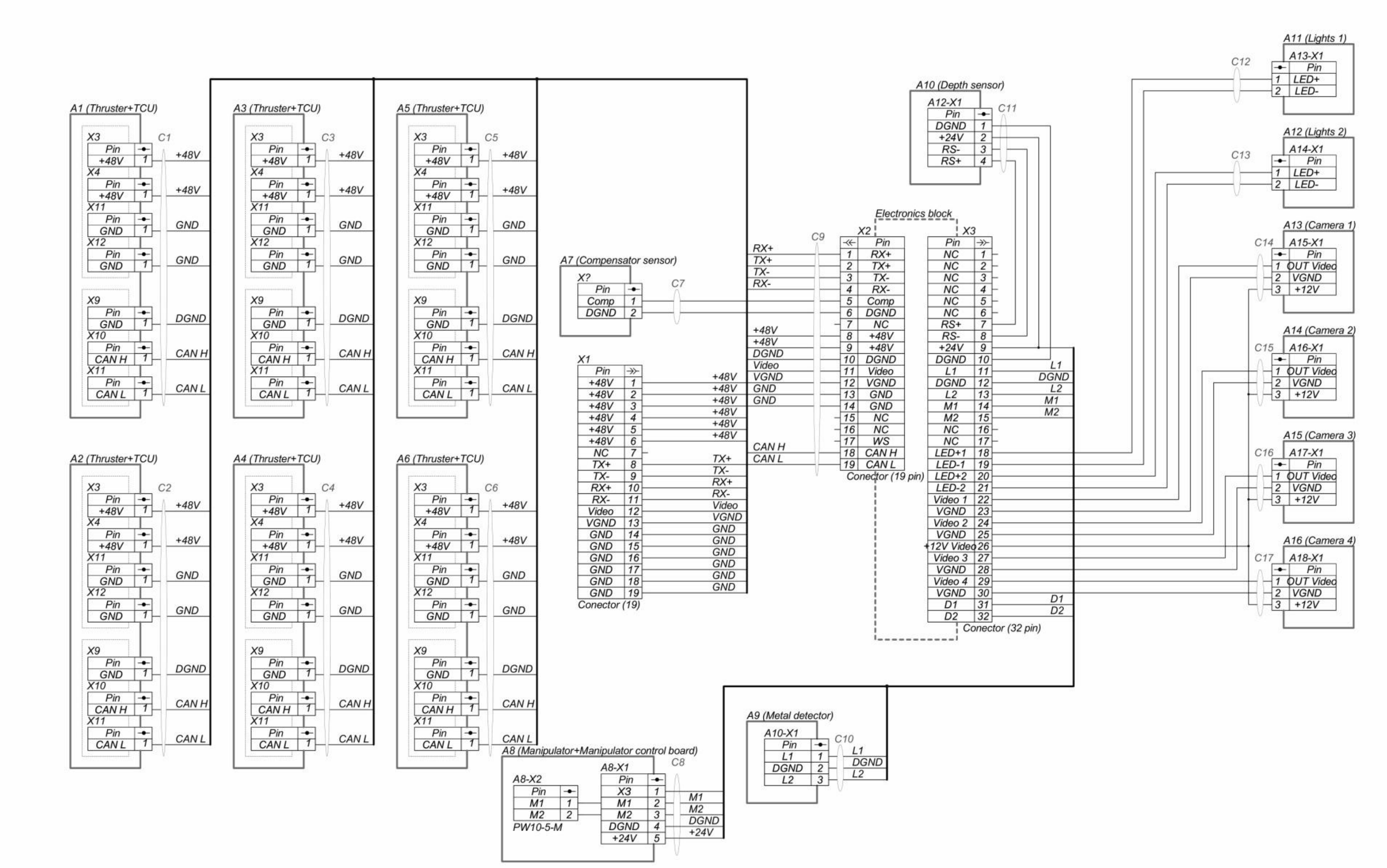
APPENDIX A - ELECTRICAL SYSTEM BLOCK DIAGRAM



APPENDIX B - ELECTRICAL SCHEMATIC



1 The tube C1, C2, C3, C4, C5, C6, C7, C9 pressure compensated

2 TCU - thrusters control unit

APPENDIX C - SOFTWARE BLOCK DIAGRAM