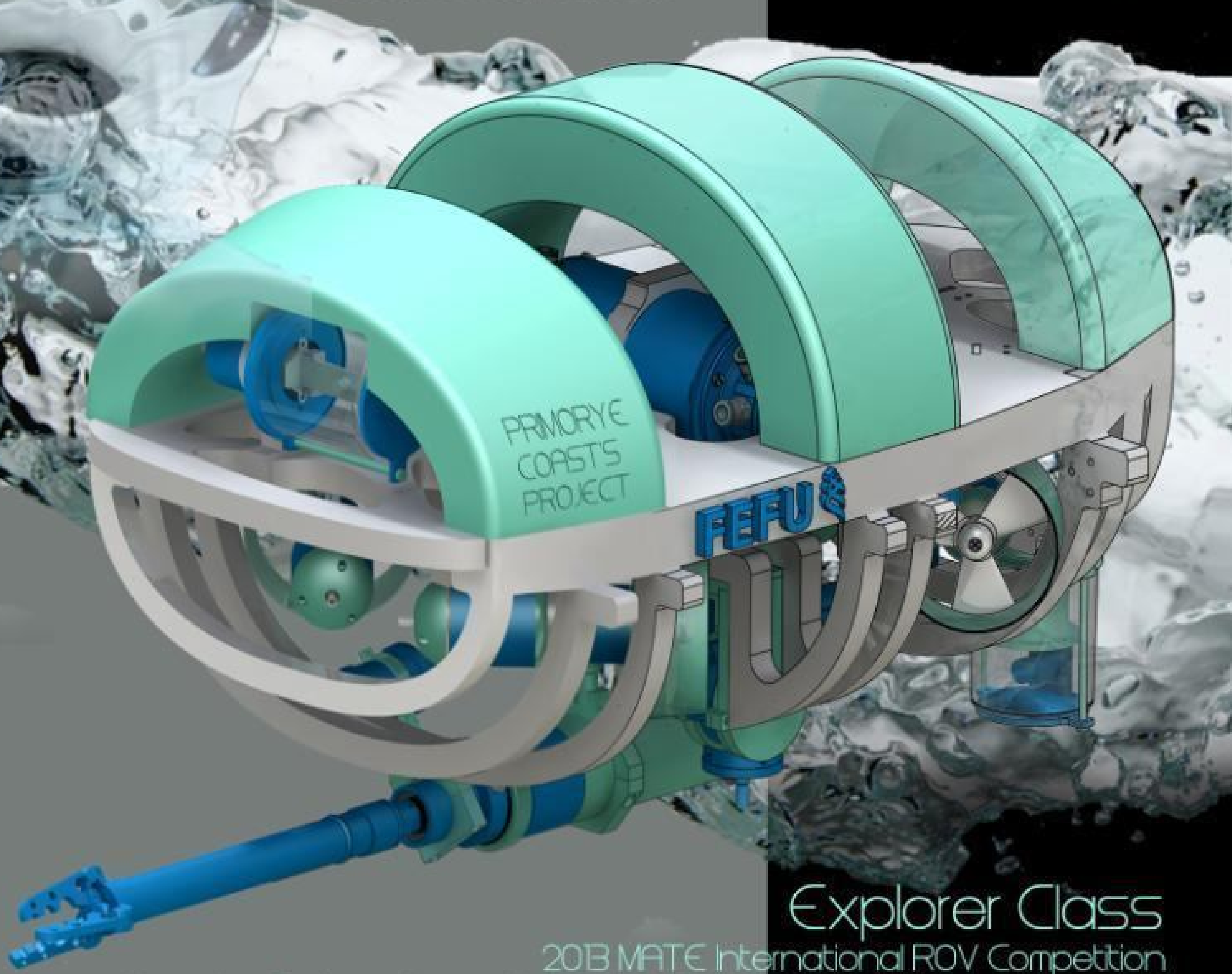
Far Eastern Federal University

Primorye Coast's Project:

Vladivostok, Russia

alien 3fd

3 freedom of degrees



Explorer Class

2013 MATE International ROV Competition

Ocean Observing Systems: Launching a New Era of Ocean Science & Discovery

Team Primorye Coast

Angelina Borovskaia 22, CEO, Head of CADD, Art designer, Manufacturing.
Anton Tolstonogov 22, Programmer.
Iaroslav Volkov 22, Head of Electronics.
Maksim Kapshiter 22, Manufacturing.
Maksim Fursov 22, Payload tools constructor, Props constructor.
Roman Babaev 23, CFO, Electronics.
Vitalii Nechaev 20, Electronics.
Vitalii Storozhenko 22, Electronics.
Vladislav Bolotov 20, Programmer, Media, Pilot.

Mentors

Sergey Mun
Andrey Kushnerik
Anton Shiriaev
Denis Mikhaylov
Igor Pushkarev

Abstract

The "Primorye Coast" company (Fig.1) is proudly presents "ALIEN 3fd" (Fig. 2), 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. In addition, special payload installed on the vehicle: a three-degree-of-freedom manipulator for many tasks, a digital camera for measuring the distance from the BIA to the secondary node, a spinner for adjusting the legs of the secondary node, a special hook for removing old ADSP from the mooring platform, a special liberation clip to install the new ADCP into the platform. Also we developed an optical transmisometer to measure turbidity over time.

Total expense for the development of the vehicle is $ 7,563.

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

Fig. 1 Primorye Coast Company

Left to right: Angelina Borovskaia, Anton Shiriaev, Sergey Mun, Maksim Fursov, Vitalii Storozhenko, Vladislav Bolotov, Roman Babaev, Iaroslav Volkov, Vitalii Nechaev.

Fig. 2 ALIEN 3fd (photo)

Table of Contents

Budget

"Before to consult on whim, consult to the purse"
Benjamin Franklin

Items (all values are in $USD)	Re-Used	Actual	Vendor (City)
Frame			
Polypropylene Sheets		810	"Plastmast" (Moscow)
Extruded polystyrene		60	"Tridekor" (Vladivostok)
Material for all housings (aluminium)		567	"Megamet" (Vladivostok)
Propulsion system			
Motor Faulhaber 4490 (6 x $610)	3660		"Microprivod" (Moscow)
Material for propellers (silicone,		100	"StarDV" (Vladivostok)
Electronic components for TCUs	135		"Base electronics" (Voronezh)
Video system			
Digital video camera Logitech C920		120	"DNS" (Vladivostok)
Analog video camera KPC-VBN190	155		"Steelesgroups" (Moscow)
AVC SONY Color EFFIO 960H (2x $190)		380	"Specvideomontazh" (Vladivostok)
Electronic components		15	"Elektromarket" (Vladivostok)
Electronic unit			
Electronic components		600	"Base electronics" (Voronezh);
Fittings		50	"Atrium" (Tolyatti)
Depth sensor			
Pressure sensor		130	"Dalzavod" (Vladivostok)
Electronic components		2	"Elektromarket" (Vladivostok)
Manipulator			
Grabber Seabotix TJG300		3500	"Seabotix" (San-Diego)
Gear motor IG-42GM		130	"ATOM" (Saint Petersburg)
Window lifter		50	IP Komaritsin (Vladivostok)
Electronic components		65	"Elektromarket" (Vladivostok)
Communication unit			
Case		20	"Omega" (Vladivostok)
Wi-Fi module		54	"DNS" (Vladivostok)
Power source		530	"Base electronics" (Voronezh)
Electronic components		100	"Elitan" (Izhevsk)

Tether			
Hose		45	"Dalzavod" (Vladivostok)
Cables	127		"Omega" (Vladivostok)
Spinner			
Gear motor IG-42GM		128	"ATOM" (Saint Petersburg)
Electronic components		22	"Elektromarket" (Vladivostok)
Transmissometer			
Flasks		10	"Plastmast" (Moscow)
Cables		55	"Dalzavod" (Vladivostok)
Electronic components		20	"Elektromarket" (Vladivostok)
Trip			
Airline tickets		18000	"Pacific Line" (Vladivostok)
Visa		1500	The U.S. Consulate General in Vladivostok
Customs services		1300	Vladivostokvneshtrans (Vladivostok)
Hotel		3900	Hotel Murano (Tacoma)
Total	**4077**	**32263**	

The total cost of the project, taking into account the materials and the cost of travel is $32263.

Mission description

This year's event dedicated to the ocean observing system. According to the mission, we need to deploy additional node Observatory, to produce turbidity near hydrothermal source, change the old Doppler velocity meter and remove biofouling from structures and instruments within the observatory. The mission is divided into four tasks.

The first task includes subtasks such as completing of the primary node and installing of the secondary node. Completing of the primary node includes realization of several sub-tasks. First, SIA is to be lowered into the block BIA. Then the CTA should be removed from the seafloor and inserted into the bulkhead connector on the BIA. Installing the secondary node also includes several sub-tasks. First, pulling the pin to release the secondary node from the elevator. Then, Installing the secondary node in the designated location at the stipulated distance from the BIA. After installation of the additional node, it should be aligned in a horizontal plane by adjusting the legs. Finally, the secondary node should be connected to the SIA.

The second task - is to design and install transmissometer in the vent field and receive data every second for 5 minutes. Using these data to draw a graph showing the change of turbidity in the water.

In the third task we have to replace an old ADCP to a new one. As a first step, we should turn off the power platform, disconnect the plug from the socket on the platform with the ADCP. We are to turn the lock located on the side of the platform and open the platform, then to remove the old unit ADCP out of the platform. After that, a new ADCP is to be installed in the platform. Next we are to close the platform and connect it to a power supply.

The final fourth task is to remove biofouling from devices.

Technical requirements to the vehicle

Having analyzed tasks, we developed functional requirements for the Vehicle. The Vehicle should be able to complete the following operations.

For the first task:

1) To raise SIA by U-bolt, to move it, and to release it accurately;
2) To picks up CTA from the bottom and to plug in it into the socket;
3) To remove a pin from the lift;
4) To grab, to pick up, and to move the secondary node to the right position;
5) To measure the distance from one object to another;
6) To rotate the handle of the legs of the secondary node;
7) To open and to close the BIA door.

For the second task:

1) To transport transmissometer;
2) To set transmissometer in the vent field.

For the third task:

1) To hold, to carry, and to set up ADCP in the right place;
2) To pull the plug out of the socket;
3) To turn the handle;
4) To open the hatch;
5) To grab old ADCP from the platform and deliver it up.

For the forth task:

1) To remove the biofouling.

Design Rationale

"Design is not just what it looks like and feels like. Design is how it works"
Steve Jobs

The vehicle was designed in SolidWork 3D. For the shape of the ROV we decided to choose the ideal hydrodynamic shape - a drop. Special attention was paid to the safety of the main systems, as well.

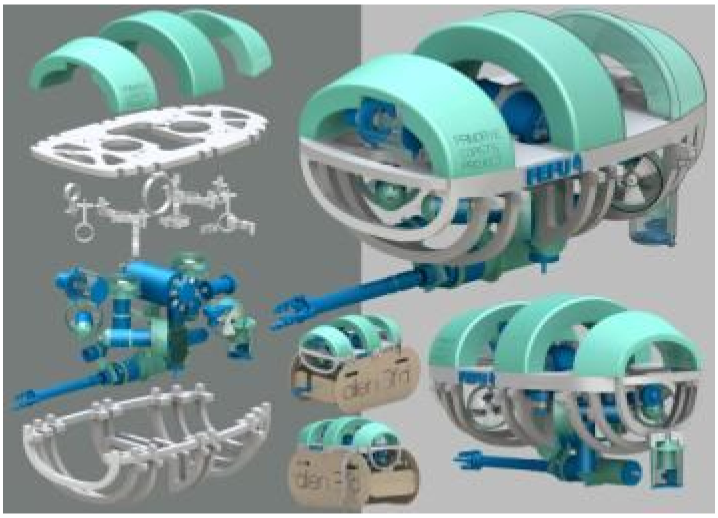


Fig. 3 SolidWork model of the "ALIEN 3fd"

The vehicle frame consists of two parts. The first part is the carrier. It is a polypropylene horizontal plate with cutouts for the attachment of most devices. The second part is protective, it is designed as a shell of 8 polypropylenes bottom ridges and 3 extruded polystyrene arches above. The frame protects the basic system of the

ROV from damage. Extruded polystyrene arches also provide the main buoyancy of the vehicle and significantly raise its center above its center of mass, with adding stability in the longitudinal and lateral axes.

Polypropylene chosen as the main skeleton material because of its high strength, positive buoyancy, and ease of processing

Most devices (2 of 4 cameras, a pressure sensor, electronics, thrusters, manipulator, etc.) are located in sealed housings for electronic items designed to stand the pressure at the depth of 6 meters. Housings are made of aluminum and consist of a casing and cap (the electronics unit housing has two caps). For sealing the containers, we used o-rings. All caps have a terminal for wires in the form of sanitary fittings. Fittings are arranged so that they are easily joined an outboard mounting tube. Outboard mounting tube is made of lightweight and flexible silicone tubing

Safety

Safety is an important issue in our team. For years of work with ROV we have formed your own safety checklist and a philosophy of safety. It is based on three "S": Safety of the ROV, Safety of the staff and Safety of the others people.

1) **Safety of the ROV**

All the electronics in our ROV is protected by reliable housings. All the housings are equipped with special sensors that monitor the condition of the electronics inside the housing:

- Temperature sensors;
- Leak sensors;
- Internal pressure sensor.

Also ROV equipped with additional safety features:

- Emergency button on the communication unit;
- Fuse on the power supply;

2) **Safety of the staff**

We have a few basic rules that every team member must follow:

- Work only in a special gear (goggles, gloves, special shoes);
- Soldering of electric circuits only after disconnection of power supply;
- The staff is familiar with the safety rules.

3) **Safety of the others people**

Also other people work with the ROV, and we care about their safety:

- Use a special nozzle on the thrusters, that protects the divers and swimmers;
- All dangerous parts of the ROV are colored;
- No protruding or sharp parts.

Propulsion system

"It takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!"

*A*lice in Wonderland

In ALIEN 3fd we decided to set six thrusters to provide 5 degrees of freedom: forward/backward, left/right, up/down, yawing, changing the pitch.

4 horizontal thrusters are angularly related to the longitudinal and transverse axis of the vehicle, with the angle being of 45 degrees. They provide forward/backward, and left/right movement, spinning and stabilization of course. Horizontal thrusters are fixed with special clamps to the top plate of the frame, where are holes for clamps. These clamps and the frame have been designed in SolidWorks and made of polypropylene.

2 vertical thrusters provide vertical movement and stabilization by depth and pitch. For mounting vertical thrusters on the top plate of the frame we've used built-in clamps.

Thrusters were also designed in SolidWorks. Each thruster consists of a motor, the thrusters control unit (TCU), propeller, housings and nozzles. All parts for thrusters, except motor Faulhaber 4490 H 048BS-K312 (212 W), were designed and manufactured by ourselves.

To create propellers and nozzles a prototype first been made out on 3D printer, and then the form was made of silicone, which is filled with plastic.

Fig. 4 Thruster

Fig. 5 Creating propellers

Housing has been machined from an aluminum rod on a lathe.

Sending a signal on the TCUs is made via CAN. Besides control functions TCUs also check current and temperature. Initialization of TCUs takes place before starting operations; each TCU is assigned its number and the direction of rotation. Control is performed as follows: the signals from the pilot's joystick come to on-board computer. There thrusts from the joystick are distributed separately to the engines and, after that, added. Then specific values for individual thrust engines are sent to the STM board, which translates them to TCU via CAN.

Video System

"A picture paints a thousand words"
English proverb

To enhance video system we decided to use digital camera for the first time. As digital cameras have some drawbacks, which analog cameras don't have, we decided to use digital and analog cameras.

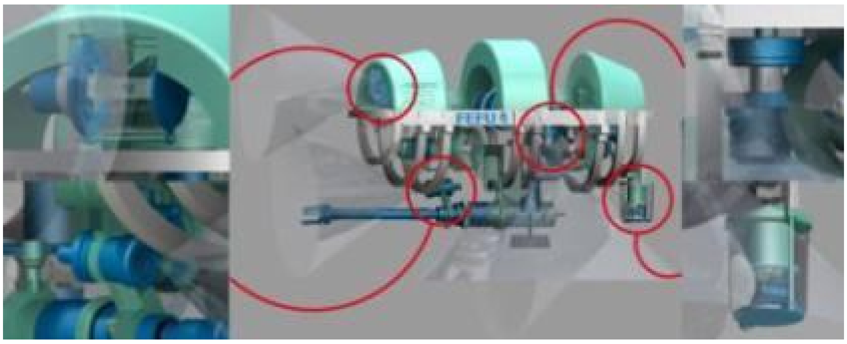


Fig. 6 Placement of the cameras

Digital Camera Logitech C920 gives fullHD signal and has a built-in h264 codec. This allows us to send high-definition video via USB and Ethernet without large latency and over-using the main processor. For capture and transfer video we use Gstreamer 0.10 and additional specially compiled plug-ins that enable work with the codec h264. However, the camera has a lower light-sensitivity and a smaller angle of view as compared with analog cameras.

Among analog cameras we have chosen modular color cameras KPC-VBN190 and “SONY Effio 960H”. Our choice is based on their small size, simple installation, high light-sensitivity (0,1 lx), and availability. Among the other advantages of the camera KPC-VBN190 is backlight compensation, useful for underwater observing, as the observed objects will be placed on a bright background. A camera “SONY Effio 960H” boasts a fairly wide (90 degrees on land) viewing angle.

Fig. 7 Digital camera

The digital camera is placed on the front part of the vehicle and looks forward. It can be rotated by 90 degrees in the vertical plane. The implementation of the rotary mechanism is provided by stepper motor. We have chosen stepper motor, because it provides an accurate rotation angle in contrast to common electric motors and its size is small enough, compared with servo. The operator console transmits on the STM board data about which way, with what speed and by how many steps the camera is to be turned.

Housing for this camera is made of plastic caps and two aluminum covers strapped by pin. On one of the caps mounting for the stepper motor controller is attached. The camera is to be mounted to its shaft.

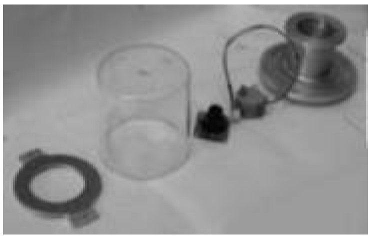


Fig. 8 Rotate analog camera

One of the analog cameras “SONY Effio 960H” also is rotational. The rotating mechanism is necessary to observe the old ADCP and the new ADCP by the same camera. The camera is located on the back side of the ROV and attached to the ridge by special clamp. Its housing as well as digital camera housing is a plastic cup and two covers strapped together.

Fig. 9 Bottom camera

Another analog camera “SONY Effio 960H” is located at the bottom part of the vehicle between the two ridges and attached to one of the ridges by clamp. This camera looks straight down, which is necessary to perform certain missions.

Fig. 10 Manipulator camera

The third analog camera KPC-VBN190 is attached to a non-rotational part of manipulator by special clamp and moves with the manipulator in the vertical plane. Housing of the camera is a sealed container made of an aluminum cylinder.

Control system

"If everything seems under control, you're just not going fast enough"
Mario Andretti

On-board

Electronic unit

The electronics unit is a heart and brain of our ROV.

Housing of electronics unit consists of a cylindrical body, chassis for the electronics boards and two caps. Left cap is used to input tether via sanitary fitting and output wires to the thrusters. The right cap has terminals for wires from the cameras, the manipulator and the pressure sensor. On each cover the leak sensor is located.

There are five boards in the electronics unit: Raspberry Pi, the controller board STM32, Multiplexer board, the board sensors and supply board. The first two boards are used to control the ROV. Multiplexer is used to switch the cameras between the two channels. Digital accelerometer and a gyroscope are located on sensor board. The supply board provides power the entire vehicle, except for thrusters.

This year we divided the control process of the ROV into two components. Raspberry Pi performs control functions and STM32 is responsible for executing function. Raspberry Pi executes all analytical functions: thrust distribution algorithms, the PID stabilization algorithm, the computation of roll, pitch and depth. Raspberry Pi sends part of the data (eg number of active camera, the command for grabber rotation) to the board STM unchanged, and uses another part (stabilization flags, stabilization factor) for its own needs. RaPi translates data from the joystick into traction of the thrusters and passes final commands on the executive board. The same RaPi constantly request information from the STM board about the current state of ROV. It transmits the obtained values to the control panel and also uses them for stabilization. STM board acts as an executor. It receives commands and distributes them to the periphery: changes the position of pins on the multiplexer, changes the duty cycle of PWM for smooth control of the three-degree-of-freedom manipulator and transmits thrust via the CAN interface to TCUs. Besides, the board constantly request information from the accelerometer, gyroscope and the internal pressure sensor via the I2C interface, digitizes the analog signal from the sensor of external pressure and reads the state of leak sensors. The data is constantly being updated and sent to the board Raspberry Pi.

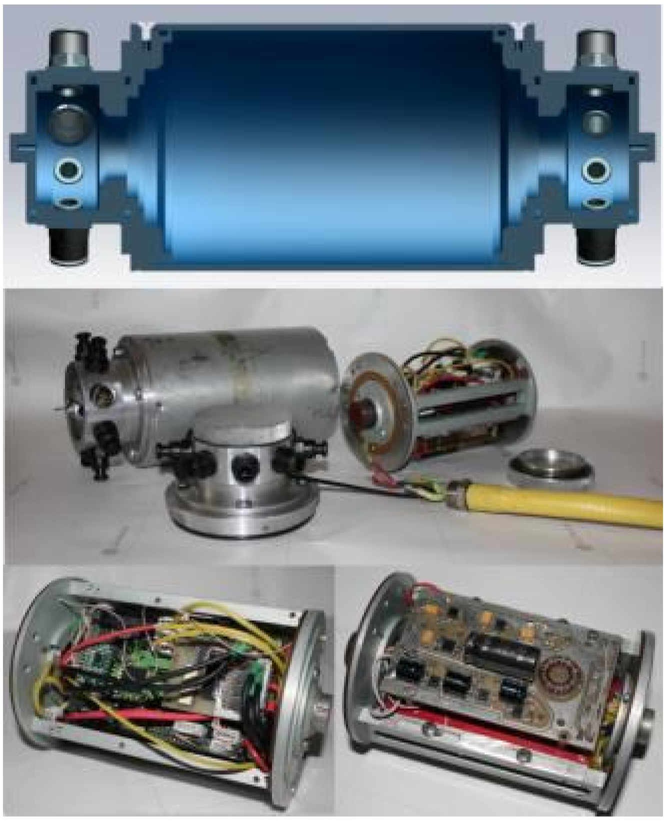


Fig. 11 Electronic unit

Using the Raspberry Pi board has given us a lot of possibilities. First, due to the installed operating system Raspbian, based on Debian, we can remotely start STM32 board, test it and, if necessary, correct code of computational functions. Second, as the board is a fully functional computer, we were able to connect a webcam to it, and send its digital video signal to the control panel via Ethernet wire.

The executive board based on the STM32 was designed by our own in Altium designer. It consists of a STM32F207 microcontroller and outputs for connecting peripheral devices. Board was originally designed so that it can be easily connected to RaPi without using wires in the shield style. To reduce the size of the board, we have designed it four layered, that's why we couldn't make it by ourselves and ordered it at the nearest (up to 3 kilometers) factory producing circuit boards in Novosibirsk. Having received the board we soldered on all elements ourselves.

Multiplexer is based on operational amplifiers AD4081. Decoder CD4555 is used as a control circuit. It receives control signals from the controller STM32, so that the image of one of three analog cameras is output to each channel.

Purpose of the supply board is to convert the DC 48V provided by the organizer, into the voltages required to supply the electronics components (24V, 12V, 5V).

The electronics firmware was written in parallel with the design and manufacturing of circuit boards. Part of the firmware we took from the last year device, e.g. the transfer of commands to the thrusters remained unchanged. Software for stepper engines and systems of PWM to control the manipulator was developed from scratch. Handler of the main loop of the executive program was greatly changed.

IAR is used as the main development environment.

Sensors

As the navigation sensors, we use board STEVAL-MKI108V2 from STMicroelectronics, containing chips: L3GD20, three-axis gyroscope, and LSM303DLHC, and combining in one case three-axis accelerometer and three-axis magnetic sensor. Our choice is due to its small dimension, high accuracy and availability of digital interface. This board is located in the housing of the electronic unit.

To measure the pressure inside the unit a digital sensor ASDX015A24R, located in the cap of the housing, is used. It`s necessary to control the internal pressure in the vehicle.

As the depth sensor we use PD100 pressure transducer disposed in a separate housing.

STM32 scans all the sensors 30 times per second. Processing data, conversion them to floating point format and linking to real physical quantities is made only by the RaPi.

As a result, package comes on the control panel containing the roll and pitch data of the device in degrees, the value of the angular velocity in degrees per second, the current depth in centimeters, the internal pressure in Pascal, and leak sensors data.

Communication

Tether

The tether is used to transmit signals between the electronic unit and the communication unit. For transmitting analog video signal, we use two 1.5mm coaxial cable with an impedance of 75 ohms. The device

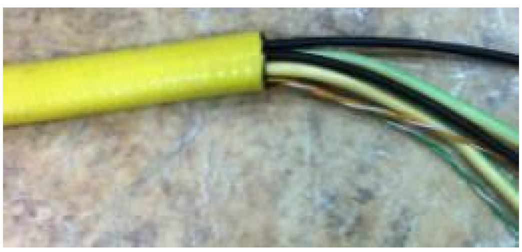


Fig. 12 Tether

requires high power (~ 1700 W), so for power supply we have chosen two power cable 6mm. For transmitting control signals we use the standard twisted pair cable.

Also, via tether we pump air to control the internal pressure in the ROV. Since we always know the current depth, we can accurately calculate and create the necessary internal pressure in the vehicle.

Communication unit

This year we set a goal to create a communication unit, which would include a quick and reliable connections, switch for power supply and connection ROV to a laptop. Communication unit consists of a power supply (48 V), the board of keys, Wi-Fi router and connectors.

We have chosen the power source RSP-2000-48, because it gives us required power, it easily fits into the finished device, it is safe, and it has its own cooling.

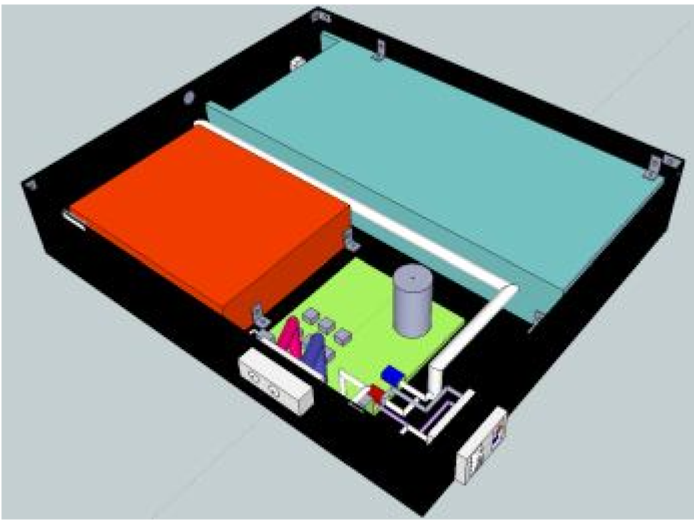


Fig. 13 Model of the communication unit

First, we have developed the board of switches, which switches power between our power supply and provided batteries, and then distributes the power between the ROV and the Wi-Fi router.

Our communication unit provides large power (2000 W). We use three transistors instead of one, to make our device more reliable. It had to be done because while charging the gate of the transistor to the desired voltage, the transistor is strongly heated and can break down. To avoid this it was necessary either to connect a transistor driver or increase the number of transistors. We have not found drivers for the p-channel transistors, so we choose the second option.

We have chosen a Wi-Fi router, as a device that connects the communication unit and a laptop. Now we do not have to constantly connect/disconnect the Ethernet cable. So, machine control became more convenient, the connection more reliable and safe, and devices more mobile.

Fig. 14 Communication unit

We designed case of the communication unit in GoogleSketchUp. Then we selected the suitable box and prepared it for assembling the components. After fixing all the components the communication unit has been completed. And after extensive testing and external processing, we have a functional device that can serve as a source of power, to provide a wireless connection, and still be convenient, safe and secure.

Top level

In this year we are decided to completely rewrite the control panel. In 2012 we used the control panel of 2011 year. The old version of the control panel was written using IDE Qt 4.1 which is obsolete at the time. Also the old control panel used the WinAPI for work with a joystick, and therefore it is not cross-platform. Second, since that time a lot has changed in the hardware of the device and the remote control unit became not suitable to use. Third, we want to increase the functionality of the console panel. We have decided to introduce the following new features:

1) Output one of the video streams on the screen. Previously, all the video went in one stream to TV output. Now we output two streams, one for the TV, another on the laptop screen. This decision was taken in order to coordinate the actions of the first and second pilot. This allows the first pilot to focus precisely on the current performance of the mission, while the co-pilot monitors the current location of the vehicle with respect to the objects of missions, monitoring the current state of the sensors, and coordinating activities of the first pilot.

2) Improved debugging. Now we can change all calibration constants without flashing. The process of debugging the device has become more interactive and fast.

3) The transmitted data packets are dynamically generated and changed, in order to reduce the amount of information transmitted via Ethernet. We transfer only the data that has been modified, so we can choose what data is to send to the on-board, and which are not.

As means for the implementation of these plans we chose SFML/C + +. This choice has been made for several reasons.

1) These tools are cross-platform.
2) C++ provides the necessary performance of our software.
3) SFML has comfortable, easy-to-use tools for working with video.

The control panel has two modes of operation: piloting and debugging. In the piloting mode video is displayed on the entire screen with a digital camera on top of a variety of video output widgets: joystick, roll, trim, various timers. In debug mode, a window with debugging information takes over 70% of the screen: engine power, the state of the sensors, the value of the stabilization coefficients, etc.

Manipulator

"Three of freedom is better than one"
Primorye Coast

For the performing some of this year tasks three-degree-of-freedom manipulator based on SeaBotix grabber was developed. Grabber can rotate in a special device which consists of housing with a gear motor and a slip ring. Via rotor shaft a gear motor transfers torque to SeaBotix grabber attached to this shaft. When the shaft rotates, grabber and wires rotate too, and the manipulator control board stays stationary. We used slip ring to prevent twisting of the wires.


Fig. 15 Three-degree-of-freedom manipulator

We choose slip ring SNH012-0605, because it is suitable for our objective. Gear motor DC IG-42GM is used to rotate the grabber. Motion in the vertical plane is provided by a window lifter of Suzuki Elf. We upgraded the original housing of window lifter to be able to use it underwater.

Board of H-bridge controlled by STM32 board transfers duty cycle of the PWM signal to the gear motor. This gear motor rotates the support shaft passing through the slip ring. Housing of the slip ring has a special hole for wire. These wires go to the stator of the slip ring and out of the rotor into the cavity of the support shaft. Shaft rotation will cause the rotor of the slip ring to rotate, while the stator of slip ring and incoming wire will be static.

Mission tools

We decided to use the three-degree-of-freedom manipulator, because the most of the underwater work consists in lifting, turning and transferring objects.

To measure the distance from the BIA to the additional node, we use a digital camera. We take into account the fact that the linear dimensions of the object on the screen are inversely proportional to the distance from the camera to the object. Having made a reference frame (when we know the distance to the object and its size in the picture), we can measure the length at any distance using formula:

$$X = \frac{W_{rep} X_{rep}}{W}$$

In this formula: X is the distance from the ROV to the object being measured in centimeters, Wrep is linear dimension of the frame object in pixels in the reference image, Xrep is the distance to the object in the reference frame in pixels, W is linear dimension of the measured object in pixels in the image. This reference frame we have done with great accuracy during the preparation for the competition in the home pool.

We use an additional electric motor for adjusting the legs of the secondary node. Manufactured device is like an electric stirrer. Adjustment of the node in the horizontal plane must be checked by a bubble level located on the top of the secondary node. The bottom camera will provide monitoring of the bubble level in the process of adjustment.

For the second task, we developed an optical transmisometer. It will measure the difference in intensity of light passing through the water. The transmisometer is a solid frame made of two polypropylene parts, with LED and phototransistor attached on the opposite sides of the parts. The housing for LED and phototransistor is made from laboratory test tubes. We use fitting filled with epoxy to seal the housing. We deliver transmissometer to the destination place by the manipulator.

Data from the transmissometer are transmitted to a data processing unit by cable. We developed it ourselves. The processing unit is connected with transmissometer via two coaxial cables inside the silicone tube. One of them is responsible for the power transfer, the other for the transmission of the information from phototransistor. The kernel of the data processing unit is an Arduino Uno board. We chose it, because Arduino is an open software


Fig. 16 Transmisometer

platform with a simple programming language and is very easy to learn. Transmissometer and a data processing unit are powered from a laptop through the USB cable. The data from the device are displayed in a laptop in the program that we wrote ourselves.

We designed a special hook for removing old ADSP from the mooring platform. "Hook" consists of a polypropylene tube and aluminum housing with the guide slot. Two springs are bolted to the tube. Springs are metal strips with a hook at the end. To capture the old ADCP operator should sit by a clamp on the U bolt, and the springs firmly fix it.

Fig. 17 Hook

We create special liberation clip to install the new ADCP into the platform. It is also constructed from aluminum body and a polypropylene pipe segment with two springs inside. A first spring is a ring-shaped, it consists of a metal wire. Another spring is constructed from a metal plate, with a hook at the end. In operation, at the end of the plate with a hook U bolt ADCP is set, it is captured by the ring-shaped spring. When we need to unhook the ADCP, operator sets it into the platform and pushes it into a bottom; thereby the spring is bent back and releases the engagement of the block ADCP.

Challenges

"A challenge only becomes an obstacle when you bow to it"
Ray Davis

Challenges that we set for ourselves

- To make a reprogrammable on-board. We decided that this year the basic algorithms controlling the device will be remotely available. Last year, having detected any error in the firmware of the microcontroller board we had to disassemble the electronics unit and connect to the circuit board for flashing and debugging. It was very uncomfortable and unsafe.
- To use a digital camera for the first time. Using a mini-computer in the electronics unit of the ROV gave us the perfect opportunity to use web cameras. Their application is not definitely good. On the one hand, they have excellent resolution and absence of distortion, on the other hand, low photosensitivity and signal delay. This is a new experience for us, we have to write adequate software and conduct experiments to prove that the cameras can be used in action.

Technical

Three-degree-of-freedom manipulator is developed on the basis of a SeaBotix grabber.

When we started to develop a three-degree-of-freedom manipulator, we considered two ideas:

1) A separate housing with a DC motor, with DC motor rotating only the front part of the grabber, transferring torque through gearing.

2) A grabber which rotates in a separate device, consisting of a gear motor and the slip ring.

Each method has its advantages and disadvantages:

Plus of the first idea is a compact size, fewer details.

Minuses are that we are to make additional parts for SeaBotix grabber design, complexity of the worm shaft of the grabber.

Pluses of the second idea are as follows. It is easy to connect to the machine, it is compact. Minus is that the design has more weight as compared with the first approach.

As a result, the second approach pluses outweigh its minuses and we choose it.

Non-technical

The procurement system at our university is arranged so that each purchase of goods turned to us to the quest with different levels of difficulty, except the cases when we bought them for our own money.

To make a payment for goods or services, we should request documents (bill, invoice, waybill, etc.) from the vendor, then we have to make the rationale prices, including at least two other vendors. Next, we need to collect more than 10 signatures (financiers, accountants, head of a laboratory, vice rectors) on these documents, only then payment is possible. Usually 2-3 days is spent for registration and signing of documents and about 3 days for payment, and only then we can take a goods.

If goods or services are not provided in Vladivostok, the issue becomes even more serious. The whole exchange of documents with the supplier is carried out via mail or courier service, which means high costs and much time. In this case, the procurement process may take from several weeks to several months.

Therefore, the purchase of any rare item turned to us in a real challenge. So we decided to make a clear division of responsibilities: a few people worked with suppliers, someone carried documents for signature, and the CFO coordinated their work.

Fig. 18 Geography of the procurement

Troubleshooting Techniques

In the design of the autopilot, we chose a synchronous serial interface SPI as a primary interface for communication between the boards and the STM32 Raspberry Pi. It provides an excellent rate of exchange and is relatively stable. When tested it did oneself justice and steadily worked in debug mode. But as soon as we turned it off, the connection via SPI broke off. At first we thought the reason being as follows. The firmware is flashed in the volatile memory, and the board stops working after reboot. However, it was not the point. Then we loaded the same firmware in another, ready-made industrial board based on the microcontroller STM32, and everything worked fine. It made us think over the situation and analyze the entire circuitry of our board. We have carefully compared it with what developers of the STM32 offered, but evident problems were not found.

Then we decided to try and change the order of activation of the boards. It was found that if you activate STM32 later than Raspberry Pi, everything works, if earlier, then no. The reason proved to be that Raspberry Pi was the master device in the connection SPI, and STM was a slave. But STM boots in ten times as fast as Raspberry if power is supplied to both boards simultaneously, and the slow board Raspberry Pi cannot notice the device connected to it in advance. As a result, we've modified the board STM32 a little and connected its supply circuit through an optocoupler with one of the leads of RaPi, so we can remotely turn off the power momentarily across the board STM32, which automatically happens each time the server is started on RaPi.

Complete testing of the ROV

Electronics

Testing of the circuit boards is carried out at all stages of the development. At the design stage we test circuit board by built-in Altium Designer tools. After pickling and tinning, circuit board is checked for short circuits. If everything is all right, we can start to install of components. After this, circuit board checked for faults. Finally, we check the efficiency of the circuit board.

Programming

For functional testing of the firmware we used on-board programmer ST-LINK/v2 with debug function of the microcontroller in real time.

Future Improvement

"Everything can always be done better than it is being done"

Henry Ford

Next year we are going to give up using separate microcontroller and on-board PC. All navigation algorithms and functions of communicating with the peripheral sensors will be located on single-board computer. This eliminates the need to develop software in two programming environments at the same time, increasing the development speed, making it easier to communicate between the low-level and high-level programmers and providing greater unification of the software. Also this will reduce the size of the electronics, simplify wiring.

Lessons Learned

"When the student is ready... the lesson appears"

Gene Oliver

Technical

1) To be aware how the designed device will be build. This will help to avoid development of structures that would be impossible to build.

2) To remember that everything is possible in SolidWorks, but in the real world constructions have a definite safety factor and cannot sustain high mechanical stress. We should use simple engineering calculations and simulate loads in SolidWorks Simulation.

3) Plotting engineering print for turners we should be aware of the process of manufacturing these details by machine, it helps create a convenient and clear drawing.

Interpersonal

Work and communication in a team are very important. Teamwork makes development process quicker, easier and helps everyone to get new knowledge and skills faster. If everyone solved only their own problems, the development process would be dragged out for a long time. Productivity will grown if the other team members help you to solve the problem. Therefore it is always necessary to help each other and give advice. This lesson we have learned in the process.

Reflections

"Just slow down for one millisecond and look into your heart. Whose face do you see?"
My favorite martian

Anton T.

I am a team member for the second year. During this time, my understanding of microprocessor technology has risen from the level of "monkey see - monkey do" to a level where I can independently set tasks, and execute them, turning to mentors for the help minimally. In addition to my professional activity, participation in the team gave me experience of working in a large team of completely different people, gave a sense of commitment to a common purpose where the contribution of each participant, however small it has been, is crucial for win.

Vitalii N.

The team is primarily a congregation of talented and motivated young people. Personally at me, work in a team let me to grow as a professional and as a person. As a specialist I understand why we need those formulas and equations that we were trying to memorize at the university. I got my first burns when working with a soldering iron, spent my first sleepless night with a cup of coffee at the computer when trying to solve another "unsolvable" problem. As for the personality achievements, I met many interesting people and greatly expanded my horizons in many areas of knowledge. And accept as my due cuff on the nape from older members of the team for a poorly done job.

Vitalii S.

At first, in the team I just asked the question: "how it works", "what to click to get it working?". But then I began to speak: "why do we do it?", "Let's try this." Then, I actually was able to make decisions. I grew up as an electronic engineer and even as a programmer a bit. When you stand in front of the real problem, you want to study and seek their solutions. I got a great experience that gave me the impetus to future development.

Vladislav B.

In three years in the team I had to deal with many different tasks that required me to study various software tools and technology in a short time: work with a joystick, video display, TCP/IP, build graphical interfaces, and more.
Software is one of the most important parts of the machine, it would be impossible to control vehicle without it. And the responsibility for the software was on me. This responsibility contributed to the development of my personality traits, made me more responsible and disciplined.

Teamwork

"Talent wins games, but teamwork and intelligence wins championships"
Michael Jordan

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, 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. 19 Maxim turns housing on a lathe

Fig. 20 Angelina solders board

Fig. 21 Team makes tether

Fig. 22 Team at work

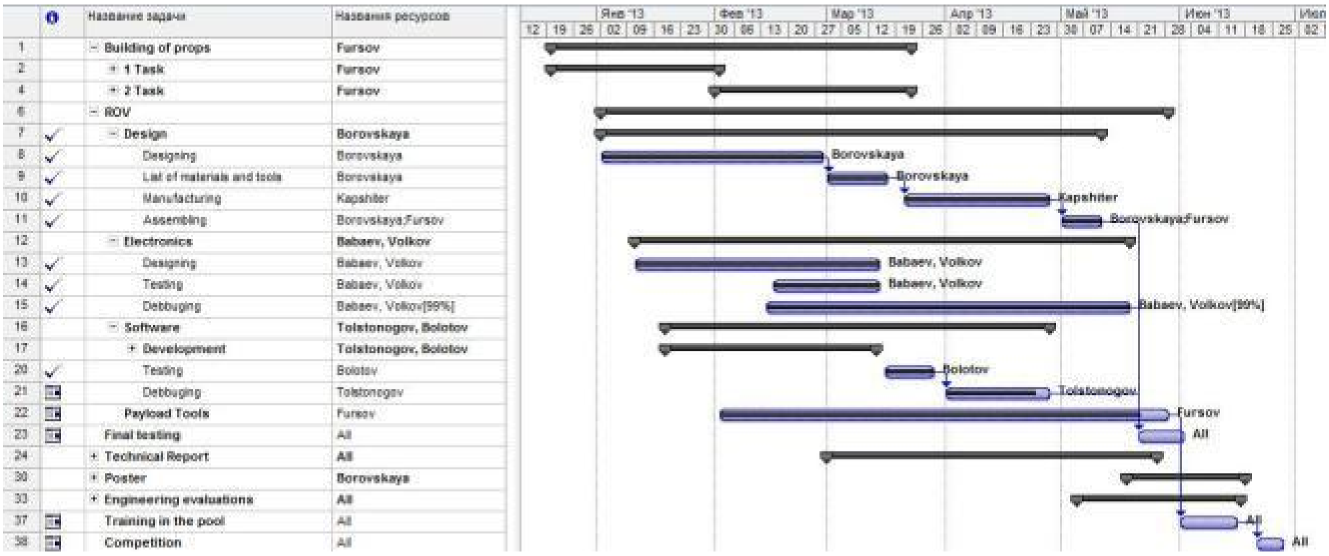


Fig. 23 Gantt chart

Acknowledgements

"If I have seen further it is by standing on the shoulders of giants"
Sir Isaac Newton

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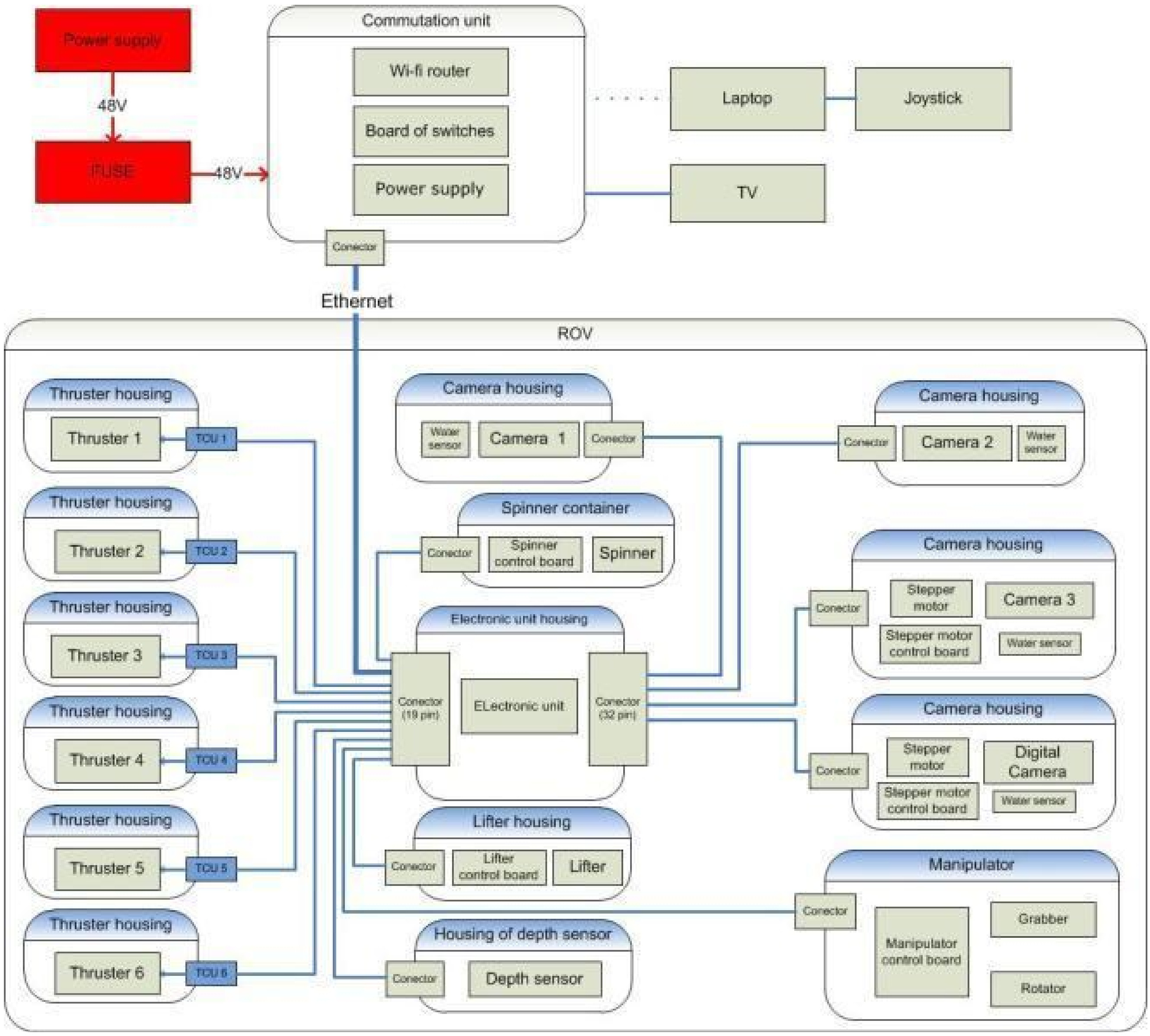
Appendix A – Safety checklist

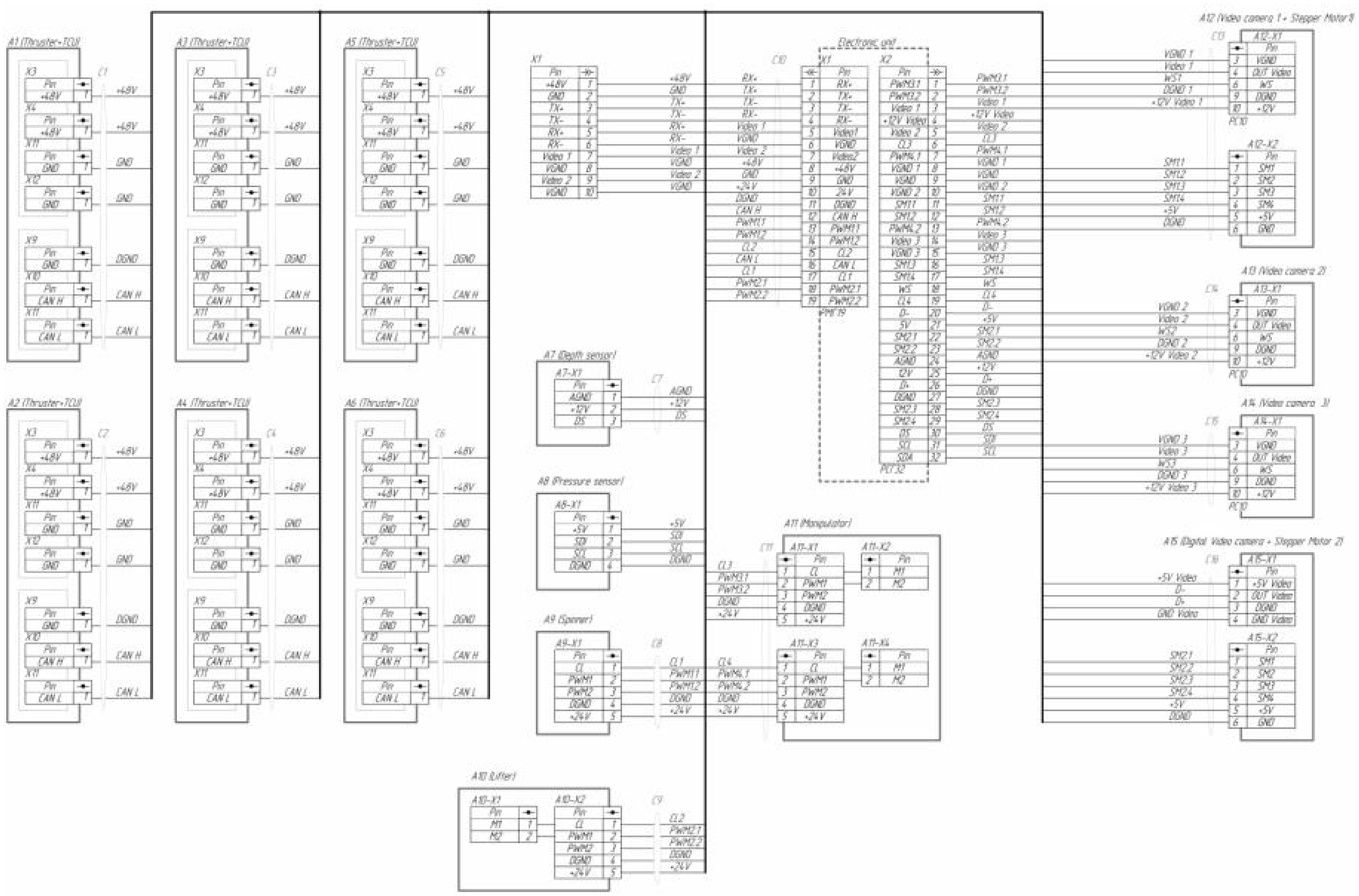
Primorye Coast Company Safety Checklist

Safety of the ROV		
1	Check fuse	
2	Check current and voltage	
3	Check data from other sensors	
4	Check all connectors	
5	Check all mounts	
6	There is a schematic diagram of the electronic unit	
7	There is a block diagram of the all electronic systems	
8	Check all wires	
9	Check for leaks.	
10	Communication unit correctly distributes power	
Safety of the staff		
1	Check medicine chest	
2	Check shoes	
3	The staff are familiar with the safety rules	
Safety of the other people		
1	No protruding or sharp parts	
2	All dangerous parts of the ROV are colored	
3	Propellers are protected by nozzles	

Appendix B - Electrical system block diagram



Appendix C - Electrical schematic



Appendix D – Flowchart software