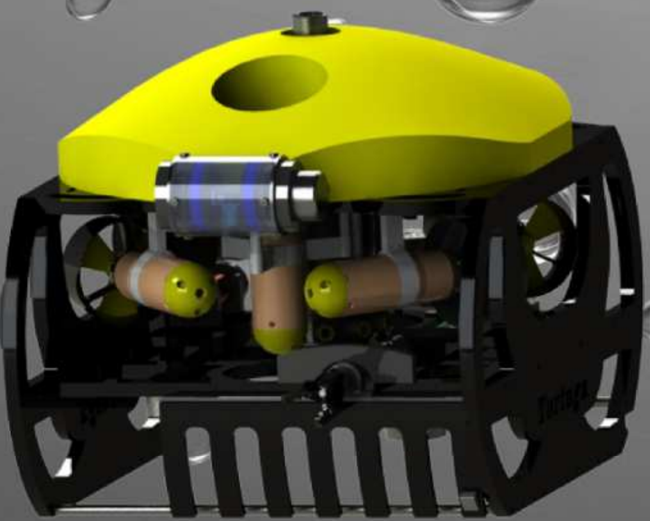
# Tortuga

## Primorye Coast



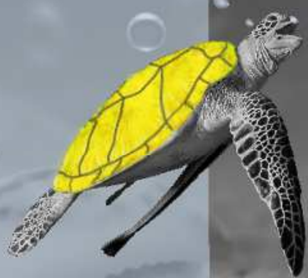

## Members:


**Anton Tolstonogov**
CEO, Programmer
**Roman Babaev**
Chief electronics
**Vitalii Storozhenko**
Electronics
**Vitalii Nechaev**
Electronics
**Denis Bondarenko**
Electronics
**Dmitrii Balashov**
CADD, Constructor
**Konstantin Borisov**
Designer

**FEFU**
**Vladivostok**
**Russia**


## Mentors:


**Vladislav Goy**
**Denis Mikhaylov**
**Alexander Scherbatyuk**

# Abstract


We, the "Primorye Coast" company, introduce our new ROV "Tortuga" in this technical report. Our vehicle was developed for efficient exploration of littoral bottom of the sea and for science data gathering.

Six thrusters provide fast and efficient maneuvering at 5 axes. Light construction of our vehicle allows easy transportation on the ground and minimizes its inertia in the water. Two rotary cameras with built-in lightning cover a total angle of 300° (150° for each camera) in vertical plane for efficient visual exploration. Easy maintenance is provided with sealed connectors and twisting caps. All aluminium parts which contact with water are oxidized and ready to use in the sea water.

*Fig.1 "Tortuga" (photo)*


*Fig.2 "Primorye Coast" company*
*Left to right up to down:*
*Vitalii Storozhenko, Konstantin Borisov*
*Dmitrii Balashov ,Roman Babaev*
*Denis Bondarenko, Anton Tolstonogov*
*Vitalii Nechaev*

Software for electronics unit was developed which can be easily remotely reprogrammed without opening the housing. Control panel was created using the most popular programming language C++ and a free framework Qt. It provides easy development and further software maintenance. Furthermore, we have developed a new modular protocol for the communication between the vehicle and the control panel.

# Table of Contents



# Relevance of the work

People have been using ships since the ancient times, but accidents when ships sink are still happening, taking not only material values but human's lives. Search and investigation of shipwrecks can help to recover lost pieces of the past. Shipwrecks' cargo may be dangerous and then requires neutralization.

This problem is particularly relevant for our region. During the one and a half century of active navigation in the Sea of Japan a great number of ships sunk. Ship graveyards are everywhere: Kamchatka, Sakhalin, Khabarovsk and, of course, Primorye coast territories. More than 130 vessels are buried only in the Gulf of Peter the Great, where our city is located. It is about a million tons of metal. Ship graveyard are located not only there, but also along the entire east coast region. A considerable number of vessels are buried near the Russian and the Reyneke islands. Their rusting skeletons are dumb witnesses of human tragedy, wars and raging storms.

In many cases, remotely operated underwater vehicles can replace divers during the work with sunk ships. This eliminates the risk for human lives.

# Mission description

This year the company had a number of tasks with shipwreck locality research and cleaning the industrial waste. In addition, an important task is to study the marine biota in the region.

The first task is an investigation of the shipwreck. It includes:

- determining the length, width, and height of the shipwreck;
- "scanning" the ship at three target locations;
- creating a photomosaic from five distinct images;
- determining the type of ship;
- determining the shipwreck's cargo;
- entering the shipwreck through the 75 cm x 75 cm hole;
- locating and determining the date the ship was built;
- recovering a ceramic dinner plate from inside the shipwreck.

The second task is to investigate a sinkhole discovered near the wreck site:

- measuring the conductivity of the groundwater;
- retrieving a sample of a microbial mat;
- recovering the old sensor string with replacing it with a new one;
- estimating the number of zebra mussels on the wreck.

The third task is to clean the area around the wreck:

- removing two bottles;
- removing the anchor line rope;
- removing the Danforth anchor and chain.

# Technical requirements

We have formed technical requirements before developing a new underwater vehicle. First of all, these were common requirements not related to the mission tasks.
The vehicle must have the following systems:

- two cameras at least for wide viewing angle;
- a manipulator for interaction with environment;
- a microcontroller to process data from sensors; microcontroller must be able to communicate with a control panel via TCP/IP.
- propulsion system providing control for three linear directions and two angles (head and pitch).

When the mission became known, we have analyzed it and have completed the technical requirements by specific ones for the mission conditions.

In order to perform the first task, the ROV should be able:

- to measure an object's length, width, and height (for the shipwreck);
- to hold an object and to maneuver simultaneously (in order to open and close the cargo container);
- to fit 800mm x 750mm x 750mm (LxWxH) dimensions (in order to pass through a hole in the ship and to maneuver inside);
- to pick up a flat object from the bottom (a ceramic plate).

For the second task, the vehicle should be able:

- to measure the conductivity of the water;
- to collect sample of the microbial mat (150ml minimum);
- to carry a 500mm x 500mm quadrat and to release it;
- to hold an object and to maneuver simultaneously (in order to recover a sensor and deploy a new one).

For the third task:

- to pick up and release objects, to hold an object and to maneuver simultaneously.

Since the mission involves manual data analysis (image analysis to count zebra mussels and to estimate the shipwreck size), we came up with three people operating the vehicle: a first pilot, a second pilot, a tether manager. The first pilot controls vehicle motion and actuators. The second pilot is responsible for data analysis. The tether manager controls the tether and probs on the vehicle.

# Design Rationale

The main purpose for the company was to create a reliable, high-quality vehicle for this year mission. Having examined the mission we came to a conclusion that the emphasis in the vehicle design should be on video processing. We have developed cameras design which allows it to be rotated on the desired angle. One of the features of our rotating cameras design are cylindric transparent housings which allowed to use RGB LED strips for indication. We have investigated camera optical distortions through experiments and have developed software for distortion elimination which we have integrated to the control panel for the second pilot.

Another important problem was to meet the vehicle size requirements for the first task. This includes not only width and height restrictions, but also a length restriction since it's necessary to maneuver inside the submerged ship probe.

We have tried a number of thruster compositions, including taking it out of the frame and considering various angles. Finally, we chose a standard composition with two vertical and four horizontal thrusters at 45° to the frame, providing an effective maneuvering in all directions. We also experimented with the vehicle frame, choosing the number of plates. We finally used two carrying horizontal plates connected with two vertical plates. Trusters, cameras, a depth sensor and an electronic unit are attached to the upper frame, all payload is attached to the lower frame. Using only one horizontal plane was not enough to align all the equipment without the vehicle size increase.

We have decided to use thrusters from the last year since they fit dimensions and specification. Thrusters are also the most expensive part of the vehicle. We have used a design of electronic unit which we have been using during last three years.

A microcontroller board for the vehicle control and a power circuit for the microcontroller board and peripherals are situated in a single cylindrical housing on a chassis. This approach is well-proven and convenient.

The structure of the vehicle is almost symmetrical because of the large number of equipment from both the front and the back of the vehicle. Bow and stern are almost indistinguishable, which allowed more easy mission accomplishment. The buoyancy covers outboard mounting tubes imitating a tortoiseshell.

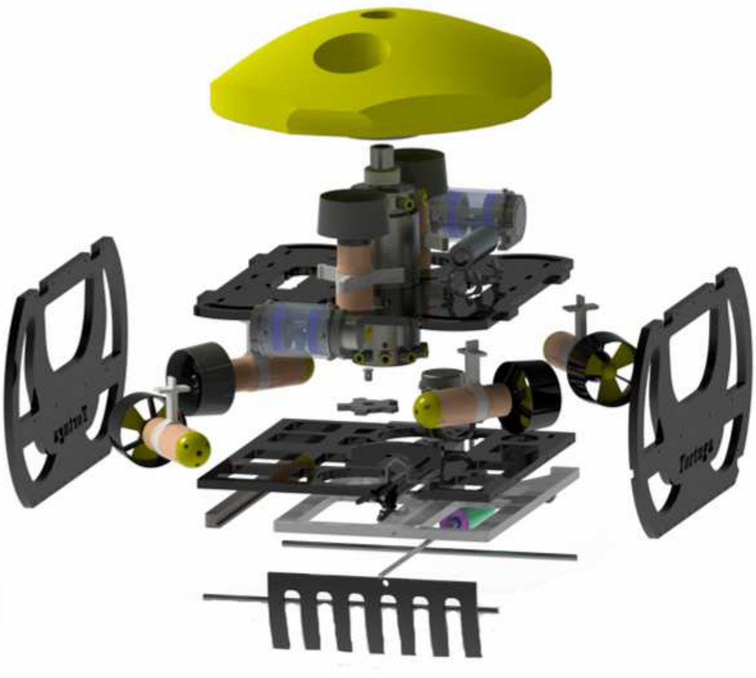


Fig. 3 The ROV explosion diagram

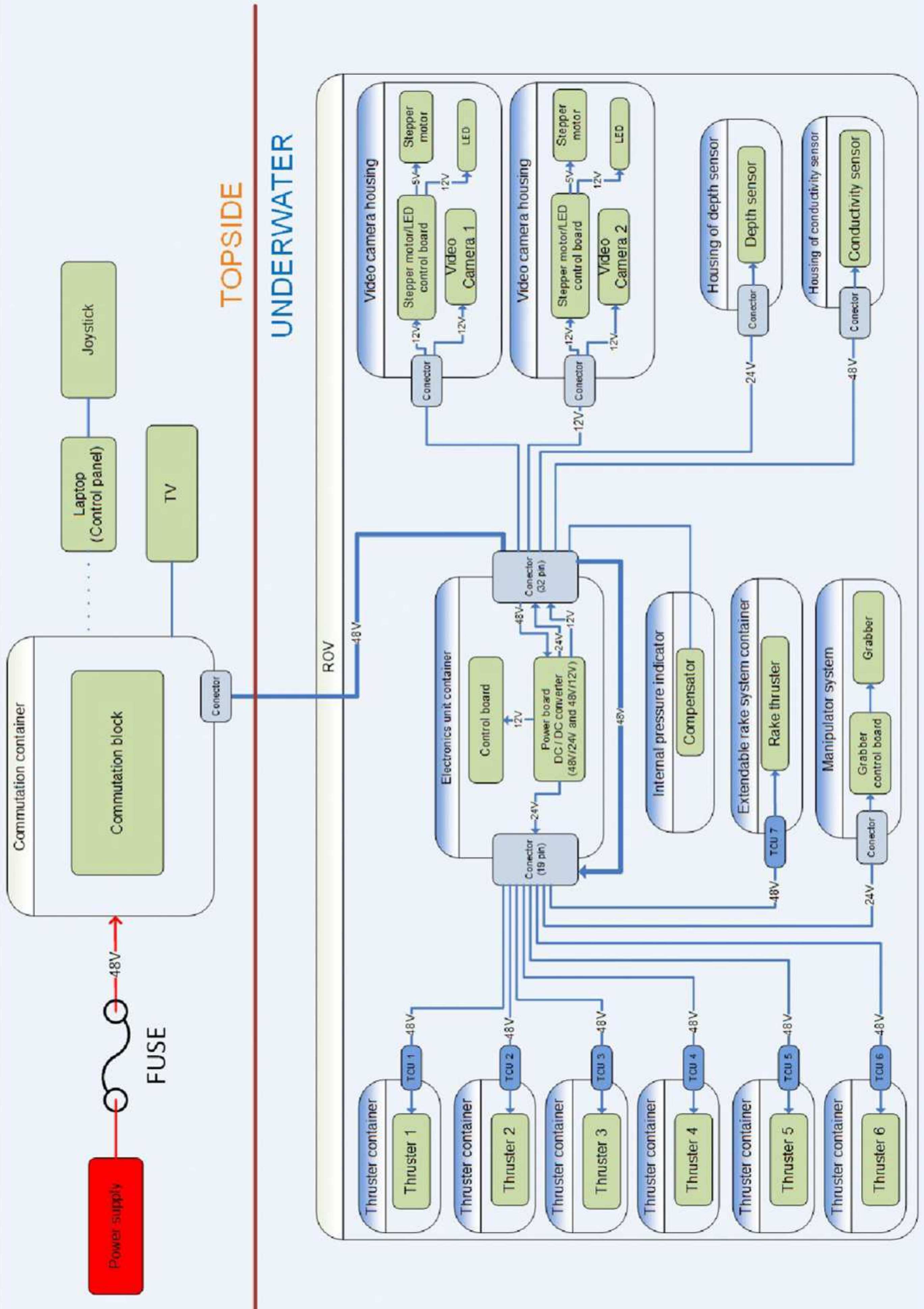



*Fig. 4 System Interconnection diagram*

# Frame and housings

We chose a classic frame structure that has long established itself in the underwater robotics ubiquitously. The design of the vehicle includes a rigid frame made of polypropylene sheets. This material is ideal for our purpose. It does not change its properties in the water, it is easy to handle, it has a lower density than water and it is sufficiently reliable. Vehicle's frame consists of two horizontal plates and two side plates. They are strapped together by stainless steel fasteners. Plates have holes for equipment mounting and cutouts for the input and output streams of water from the propulsion system. All equipment is mounted on clamps. Clamps made of the same material as the frame. They are durable and tough enough to hold all the equipment. Clamps can be easily removed along with the equipment. It facilitates a repair or maintenance of the ROV.

The basic devices are mounted on the top plate. It includes an electronics unit, 4 horizontal and 2 vertical thrusters, 2 rotary video cameras, a compensator and depth sensor. Sealed housing of electronics unit is placed vertically in the center of the vehicle. It is attached to the top plate by a clamp. It makes easy to get out the electronics chassis.
The cable connecting device to the surface comes out from the top cover of the electronics unit housing.

All payload actuators are located on the bottom plate: a rake sliding system with its own control unit, a manipulator, a conductivity sensor and a device for agar collecting.

A special attention was also paid to the tightness of all housings with electronics.
Wall thickness of all housings was calculated using a specialised software. Sealing of all housings is carried out by means of O-rings individually selected for each housing.

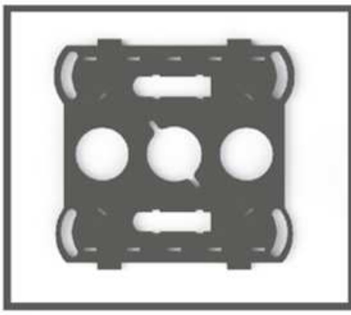


*Fig. 5 Top horizontal plate*

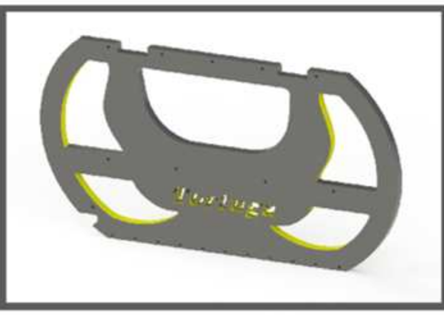


*Fig. 6 Side plate*

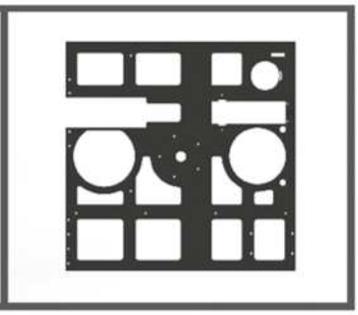


*Fig. 7 Bottom horizontal plate*

# Control System

We have divided the vehicle control in two logical parts. The first part is the "top" (remote control panel). The first pilot works directly with it. All the telemetry of the ROV is displayed on a remote control laptop with a GUI software (a control panel) developed in our company. The control panel also generates control signals for the ROV at the same time. The second part is the "bottom" (electronics unit integrated in the ROV). It receives control signals from the control panel. It also responsible for data processing from all sensors of the vehicle and for communication with all peripheral devices (thrusters, camera control unit, inertial sensors, depth sensor and others). Communication between these two parts is also an important component.

## Control panel

The control panel is implemented in C++ using Qt development environment. The program is designed to run on linux-based systems (Ubuntu 12.10).

Remote control requires the pilot to control the vehicle and monitor its telemetry. By telemetry we mean the data from the inertial measurement unit /IMU/ (angular velocity in three axes and pitch and roll), depth, value of internal pressure, data from internal ADC and leak/compensator status. Joystick for vehicle motion control is connected to the laptop. Pilot can switch between two cameras on the TV, rotate them and switch stabilizations using joystick. Besides, the first pilot can switch lights in camera housings and set limits for thrust propulsion using the laptop keyboard.

There is an additional menu for the remote reprogramming of the electronics unit. A config file for the control panel contains calibration data for all sensors, coefficients for depth, pitch and heading stabilizations.

## Electronics Unit

The electronics unit is based on the TE-STM32F207 board, that has all the necessary interfaces for us: CAN interface for thruster control, ethernet for communication with the control panel on the surface, UART interface to control rotary cameras and toggle LEDs and I2C interface for data reading from IMU. We have developed a shield, which is mounted on the board and provides all the necessary connectors. We have placed a multiplexer on it to switch cameras on two different channels and have mounted the inertial sensors at the same place.

Microcontroller board in the electronics unit receives data packets from the remote control and generates control signals to actuators.

Power board is also located in the electronic unit. It provides the power to all electronic components, except a propulsion system. The propulsion system is powered directly from the surface electrical source. The power board and the microcontroller board are mounted on the chassis by plastic racks. The electronic unit is located in a sealed container with two covers. There are 10 fitting holes in each cover to connect wires from other devices. Top cover has a connector for the tether. This arrangement allows to connect and disconnect the tether easily. This type of design also allows a convenient and safe transportation of the ROV during a travel.

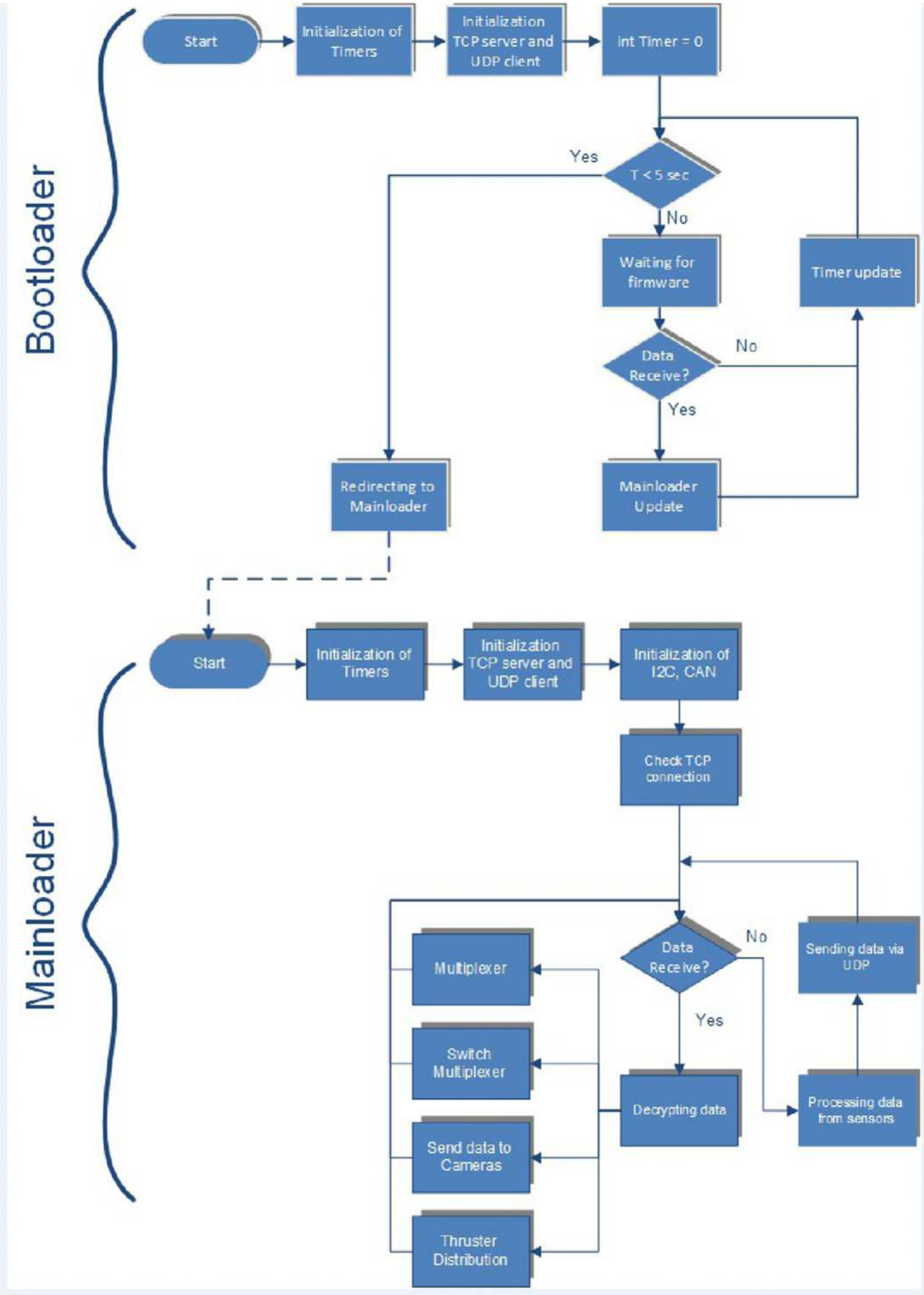
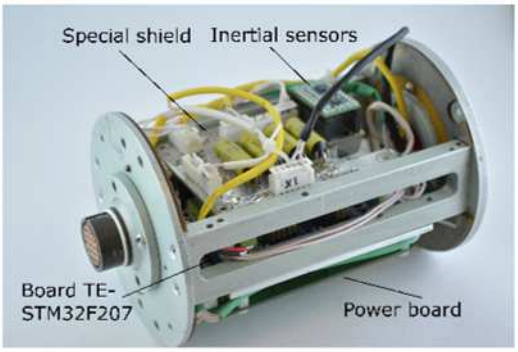



*Fig. 8 Flowchart Firmware*

# Electronics Unit



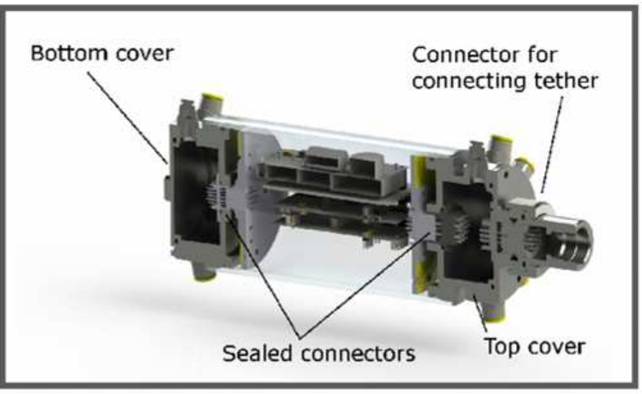




*Fig. 9 Open electronics unit*

*Fig. 10 Final render of Electronics unit with covers*

# Communication system

We have developed an application-level protocol for effective communication between the control panel and the electronics unit. Microcontroller board collects telemetry of vehicle systems N times per second (N is defined in the configuration file) and send it to the control panel using UDP protocol on the transport level. UDP was chosen due to the fact that sending telemetry to a pilot has a "streaming" nature, and loss of some packets is not essential. On the other hand, control commands from the control panel are critical and therefore we send them via TCP protocol that ensures data integrity. Moreover, these packets are sent only as necessary. We have used a UDP server for this communication scheme in the control panel, and a TCP server on the on-board microcontroller.

Another important innovation is our way to code the data. Both TCP and UDP packets are formed in the same way: they consist of several modules that are logically isolated from each other (eg data gyroscope module, data thrust module and others). Each module consists of the size of the data, a unique title for each module, and the data itself. This way for data encoding provides uniformity and easy addition of new modules to the data exchange.

We have mounted six thrusters on the Tortuga providing 5 degrees of freedom: forward/backward, left/right, up/down, heading rotation, pitch rotation. 4 horizontal thrusters arranged at the angle of 45° to the longitudinal and to the transverse axes of the vehicle. They provide forward/backward transitions, left/right transitions, rotation in a horizontal plane and heading stabilization. This arrangement allows propulsion with almost the same speed in any direction on the horizontal plane. Two parallel vertical thrusters provide vertical motion, depth stabilization and pitch control.

Each thruster consists of a brushless motor, a thruster control unit (TCU), a propeller, a sealed housing and a nozzle. Sealing of the motor shaft is carried out by a shaft sleeve. All thruster components, except the motor Faulhaber 4490 H 048BS-K312, were designed and manufactured in our company. We have produced prototypes for propellers and nozzles on a 3D printer. Then silicone forms were made based on prototypes. Using these forms, we have manufactured plastic parts of propellers and nozzles.

Thruster housings are made of AMg5 aluminum rod using computer numerical control machines.

Communication with TCUs is done via CAN interface. Data packets come from the microcontroller board. It contains the rotation direction and the desired thruster speed. TCU also measures thruster current and temperature in housing. It can send these values via CAN and Ethernet to the control panel on request.

TCUs are initialized when the main microcontroller starts: each TCU board receives its own identifier and the direction of rotation. The motion control is performed as follows: signals from the joystick (signals on the run, head, depth and pitch) are transmitted to the electronic unit from the remote control laptop via TCP. Signals are distributed among thrusters by a simple addition for each axis. Then this distribution is transmitted to each thruster via CAN interface. We use PID regulators for all stabilizations (depth, heading, pitch).

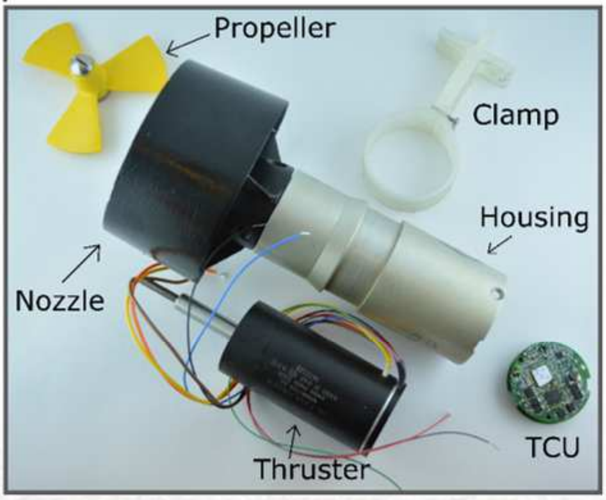



*Fig. 11 Disassembled thruster*

# Sensors

One of essential tasks for this ROV is collecting the environment data. The data can be received through the video channel or through sensors which control the vehicle position and orientation.

## Video cameras

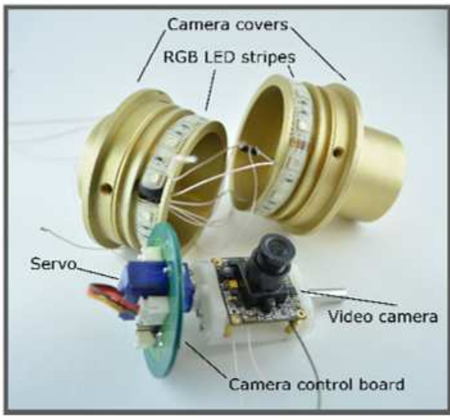
We use two analog video cameras SONY Effio 960H. They have a high photosensitivity (0.001 lux) and 90° view angle in the air (70° in the water). One camera is disposed in the front part of the vehicle, the other is in the back. Cameras are identical so we will consider a design of a single camera further.

The camera is placed inside of a sealed housing. The housing consists of an 80 mm acrylic tube and two aluminum caps. A board with electronics is placed inside one of those caps. The camera is mounted on a turntable inside of the housing. The turntable is attached to a shaft of a 5PCS x SG90 Micro 9q servo. The camera can turn 180° in a vertical plane. Camera rotation increases the view area and provides a front view and a bottom view for the seabed inspection. Clamps were designed to attach cameras to the vehicle. They are made of 15 mm polypropylene.

The camera design assumes two RGB LED stripes. They are attached around caps inside of the housing. We use it not only to illuminate the space around the vehicle but also to report malfunctions of the vehicle duplicating the control panel. For this reason we have used RGB LEDs. It changes color according to the current malfunction.

Camera control board is used in order to control the servo and LEDs. It is connected to the main controller with RS-232 interface. A MAX3232 chip was used to eliminate the noise in communication channel, it increases logical levels of the signal. Camera control board controls the camera rotation angle and the color of LED stripes. Camera controller waits for the next message from the main controller. The address in the message is compared to the camera address and if it is identical, then the next 4 bytes designate the color of stripes and the rotation angle of the camera.

The servo is mounted directly to the camera control board providing less size of the device. The camera plate is attached to the servo shaft from one side and to a rack on the opposite cap from the other side. This provides reliability of the rotary mechanism and better stability of the camera.



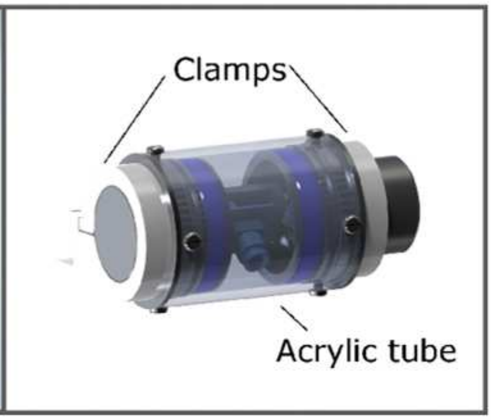




*Fig. 12 Disassembled video camera* *Fig. 13 Final render of the video camera*

# Inertial measurement unit

Stabilizations of roll, pitch and heading should be used in order to control the vehicle efficiently. Stabilization needs data which is provided by an inertial measurement unit. It consists of a L3GD20 accelerometer and a LSM303DLHC gyroscope. This sensor is quite cheap and provides the required precision.

We get three projections for the current acceleration from the accelerometer. A matrix transformation is used to take the relative position of the accelerometer into account. The matrix is computed using four measurements of the accelerometer in a static vehicle position (gravity acceleration) compared to the actual vehicle orientation.

Similar transformation is hard to perform for the gyroscope, so we have arranged it along the vehicle axes.

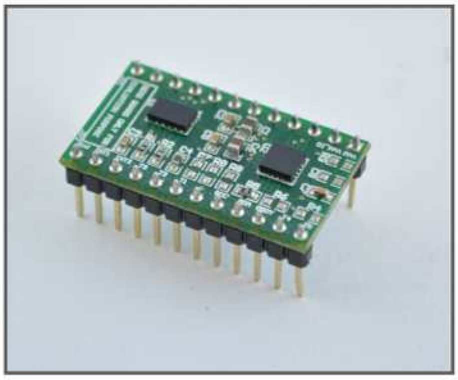


*Fig. 14 The inertial measurement unit*

# Leak sensors

The fact of penetration of the water in a sealed housing is detected by a leak sensor. These sensors are disposed in each housing. Each sensor is a conducting plate divided in two parts with a thin non-conducting stripe. One part is connected with a microcontroller leg on 3.3V, while the other is connected with the GND. When the water is on the stipe, it connects two parts and the voltage goes down on the controller leg. The leg voltage is used to detect water in the housing.

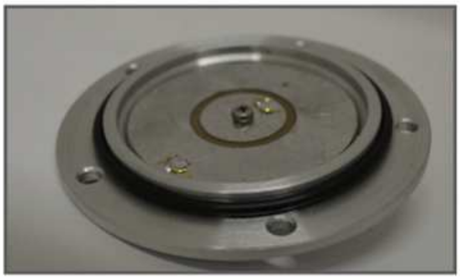


*Fig. 15 The leak sensor*

# Internal pressure indicator

While the ROV goes deeper, the water pressure increases. It should be compensated by the internal vehicle pressure, otherwise there will be a redundant pressure on thrusters sealings. Due to this reason the pressure difference inside and outside the vehicle should be known and for the according pressure change. We use pressure compensator for this. It is a small rubber ball with a button inside. The pressure inside the ball equals to the pressure inside the vehicle. If the water pressure is more than the internal pressure, the ball shrinks and the button closes a switch. The signal is displayed on the control panel and this is a signal to a tether manager to increase the pressure using a pump.

*Fig. 16The internal pressure indicator*

# Depth sensor

The current depth is determined by using a pressure sensor. The sensor is analog, the consumed current is proportional to the pressure.

The sensor is mounted on the upper plane. It consists of 6 parts: a hollow cylinder, front and back sealing caps, a sealing connector (PC10) and a sensor PD100-DI itself. The front cup has detachable plane for the convenience of the electrical mounting.

The sensor is demounted easily. Both sealing caps has a screw joint. It saves time significantly and allows easier troubleshooting. The housing sealing is provided by O-rings.

# Tether

The vehicle is connected with a commutation and power supply block by the cable. We use two coaxial cables 1.5mm with 75 Ohm resistance of the video signal. Ethernet cable is used for other data. The vehicles needs large power (~1700W), so we have used two 6 mm power cables.

The air is pumped through the tether in order to align the internal and the external pressure.

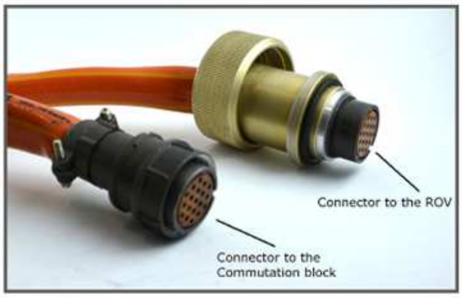



*Fig. 17 Tether connectors*

# Power supply

The vehicle needs power supply, but different parts of it needs different voltage. So we use DC/DC converters for different voltage both in the commutation block and in the vehicle.

Conditions in our lab are different to the competition conditions. Due to this fact we have developed a commutation block for both 220V and 48V. The external power is provided by an AC network with 90-240V voltage and 50-60Hz frequency or a DC source on 48V. There is no need to plug the lock to form one source to another.

*Fig 18. Open and close commutation block*

Sources can be plugged simultaneously and one of them is chosen with a switch. The system is protected from an incorrect polarity and a short circuit.

The transformation from AC to DC is performed by an AC/DC converter MeanWell RSP-2000 with input plugged to a switch board. A 48V DC source is also plugged to it. We use a circuit of our own design with field-effect transistors in order to commute power sources. The circuit allowed to avoid the usage of large mechanical switches and high-power diode rectifiers. The system is placed in a shockproof water resistant case for protection from the external factors. A front panel with controls and indicators is mounted in the case. A fan and vents are also mounted on the front panel for power components cooling. The panel is designed in the SolidWorks system and produced using waterjet cutting. Inside the case there is also a router for remote connection of the vehicle with the commutation block and an active cooling system. According connections are arranged on the front panel. 48V from the commutation block are applied to a power circuit in the electronics unit and to thruster control units. The power circuit converts 48V provided on the competition to the voltage for electronics unit components (24V, 12V and 12V separately for the video system). 24V are used to power the manipulator and the depth sensor. 12V are used for the main microcontroller and camera control circuits. 12V-video provides the power to cameras.

## Device for agar sampling

For the second mission execution it is necessary to collect a microbial mat which is simulated by agar. Agar has a dense structure - this property was taken into account during the development of a sampling device which can easily take samples of the material.

Its structure is based on a hollow metal cylinder with a metal axle attached to one of its sides. This axle supports a rubber circle that unbends during the sampling process to let agar get into the flask. When the vehicle is emerging the rubber circle shuts under its own weight.

An easily loosened cap located on the other side of the cylinder makes it simple to take agar out. Also the design provides a cap-holder that is used for centering the whole structure. There is a sinker at the top of cap-holders to make this process easier.


*Fig. 19 Device for agar sampling*

## Manipulator

In the majority of missions it is necessary to either take, carry, open or close something. It was decided to use a manipulator with 2 degrees of freedom and we have installed a Seabotix grabber onboard. The grabber is controlled by the PWM signal, which goes throw the H-bridge board. PWM signal regulates the speed of compression. Grabber circuit-board is located inside and is hermetically sealed with a specially designed piston . Second degree of freedom is realized by extending the rake system.

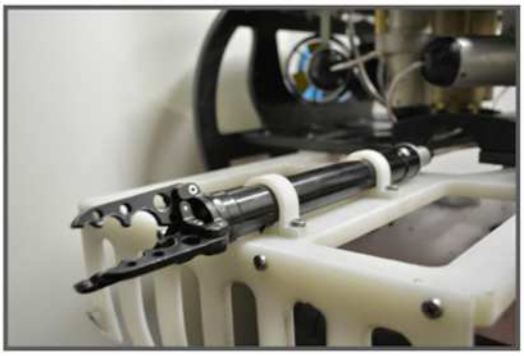


*Fig. 20 The Grabber placed on the moving rake system*

## Conductivity meter

We have developed a device for measuring the conductivity of the water. It consists of a circuit board that generates square waves of varying frequency and graphite probes connected to it. Probes are located outside in contact with water. Water conductivity is proportional to the resistance between probes. The board's design is based on a NE555 timer. Timer pulse frequency is proportional to resistance of the probes.

Timer's output that generates a square wave is connected to the microcontroller board in the main electronics unit. Microcontroller's firmware measures the frequency of the meander and calculates the conductivity of the water. These data are transmitted to the control panel.

Sensor board is located in a sealed cylindrical polypropylene housing with probes outside. To eliminate the interaction with the ground, two decoupling device were installed onboard: DC-DC Step Down Converter 48V -> 12V and a galvanic isolation Adum 1201.

# Extendable rake system

In several missions we need to grab different objects that are much bigger than our grabber can handle, such as a flat plate and bottles. They are extremely difficult to capture and require a number of emerges to raise them all to the the surface. In order to get all the items in a single emersion, we have developed a special rake system placed underneath the bow of the vehicle.

It is a container limited from the top by an bottom plate frame, from the sides - by side plates of the frame, and it's rear and bottom parts are from kevlar mesh. There is "rake" located in front of it. It can be pulled forward by the motor located on the bottom of the supporting frame. Volume capacity and width are calculated in such a way that both bottles and plate can fit there simultaneously. Thus we are saving time reducing the number of emergies.

Another advantage of this system is that the manipulator is also attached to it. Thus we can pull out or retract manipulator. Thereby we can change the length of the vehicle for easy maneuvering inside the shipwreck.

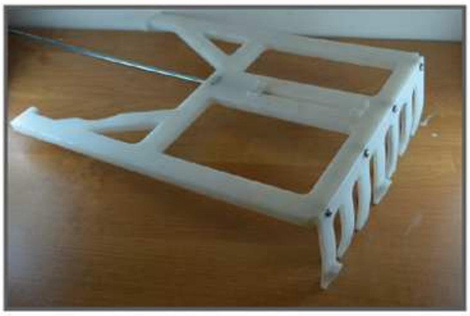


*Fig. 21 The extendable rake system*

# Size determining method

To determine the size of the ship, we refused the mechanical devices usage like roulette, because this method is very unreliable and requires high pilotage skills. We have chosen the system based on our video camera, especially considering the fact that after a drop of the measuring square on the wreck we'll have an object with determined dimensions in view.

This method of measuring the size of the objects is based on the fact that the linear dimensions (size in pixels) of objects on the picture are proportional to their real size (in a pinhole camera model). So having an object on the picture with determined dimensions (in pixels and centimeters), we can easily calculate the size of any other object according to it's size in pixels.

To implement the system, we have developed software that receives data from a TV tuner which is connected to an analog camera system. The software restores the real picture, taking optical distortion of the camera into account. We have used the OpenCV video library, which has all the necessary functions for camera calibration and distortion elimination. We determine the width and length of the sunken ship by placing lines on image and counting real size based on the exact dimensions of the measuring square. The same software is used for an automatic processing of the number of mussels located on the picture.

# Challenges and Troubleshooting techniques:

## Complete vehicle testing

### Electronics

From the very beginning of design process all circuit boards are checked for errors when compiling wiring. All developed boards are mandatory checked for a short circuit. All boards are washed in detergent to remove residual rosin after the fabrication. Each electronics has a multimeter, an oscilloscope and a power supply with a current control at hand.

### Programming

In software development, all modules are tested separately in debug mode, that simulates the real vehicle, before integration onboard. This allows us to check in advance that all the features are working correctly before installing the software to real devices.

### Design

The necessary part of the design process is a testing of all the elements on SolidWorks Simulation of torsion and bending. We verify an approximate pressure that parts of the vehicle can withstand.

## Technical challenges

This year, one of the main problems was connected with the TCU boards. After multiple runs in the pool we got one of the thrusters not working. After disassembling, we found that the TCU seems to be misfunctional. Visual inspection revealed no problems. We tried to start the vehicle without this thruster and we lost another one. We connected broken TCU's to the test bench. Benchmark revealed no errors either. Then we unscrewed an autopilot cap to check a junction with thrusters and found a condensation on the cap. Therefore we have cleaned and dried thoroughly cap of the autopilot and everything became to operate properly. Afterwards we made a detailed examination and investigated that during the run in the pool we have created a positive pressure inside the housings about 7 kg/cm^2 with our pump. Because of this one of the caps slightly bent and water got inside the electronics section, which caused the failure of the thrusters. After that we installed a internal pressure indicator onboard. Thanks to this upgrade we have additional safety feature on our vehicle.

## Company challenges

One of the biggest challenges this year was the small number of mentors who could give a piece of advice during the development of all subsystems. This problem was solved by valor and call of duty of one of our mentor, who spent a lot of time and energy helping us with advices on different fields of design and teamwork.

# Future Improvement

During this year design process the main problem was to pack the vehicle in the required dimensions. We found that the electronics unit housing is the most critical place in that issue. It was hard to diminishing. We plan to divide whole electronics unit in several smaller modules, which can be placed on frame more compact and thus to reduce vehicle dimensions.

Moreover, our propulsion system draw huge current on a relatively small thrust. We found excellent thrusters recently, which have almost the same cost in comparison with old thrusters and provide more powerful performance. We are planning to install it on the vehicle for the next year. It provides more effective propulsion system and simplifies electrotechnical installation because of less wire section.

# Lessons learned

## Technical

This year we tried to create our own electronics unit consisting of three separated boards which fit together by connectors. Such construction would provide us a convenient layout of electronics module and ease of debugging and tuning. We ordered boards using our own sketches, but a lot of problems, which we didn't noticed upon the design, arose during the assembly and the debug. Several chips broke down and we had to use our fallback - to use a debug board TE-STM32207 and a shield of our design (like Arduino Shield). As a result, we got a simple lesson: complex work demands long-lasting, very attentive and thoughtful approach. It is important to check all boards several times before production . We have a true proverb in Russia: "Measure seven times and then cut once".

Except negative experience we have received a lot of positives. We developed fundamentally new cameras, learned how to make parallel development of several logical independent hardware and software systems with pre-elaborated communication interface.

## Interpersonal

We learned competent time-management, coordination of the various subgroups. Within one year of work we understood that only coordination of actions and personal responsibility of every person of the team provide success.

# Safety Philosophy

Safety is important part of work with ROV. Everything starts with safety: from designing to the vehicle launch. Our philosophy is based on standard rules respecting that we provide the safety of the team and another people.

List of rules that we keep:

- Work in a protective clothes.
- All dusty and noisy work must be carried out separately from electronics.
- All naked wires must be isolated before power connection.
- All sharp and protruding parts of ROV are not allowed to create.
- All dangerous parts of the vehicle must be marked by stickers and labels.
- Everybody must keep the workplace clean.
- The safety of switching on must be checked before start using a check-list.

We have developed several new rules this year based on the experience gained:

- Galvanic separation unit must be used when using oscilloscope.
- Wrist straps must be used when working with electronics.
- Electronics must be cleaned before start.

| Safety of the ROV | | |
|---|---|---|
| 1 | Check fuse | |
| 2 | Check current and voltage | |
| 3 | Check all mounts | |
| 4 | Check the tether | |
| 5 | Check all connectors | |
| 6 | Check all wires | |
| 7 | Check for leaks | |
| 8 | Check the polarity of the power supply | |
| 9 | Communication unit correctly distributes power | |
| 10 | Check all ROV system | |
| Safety of the staff and the other people | | |
| 1 | The staff are familiar with the safety rules | |
| 2 | Check medicine chest | |
| 3 | Check shoes | |
| 4 | No protruding or sharp parts | |
| 5 | All dangerous parts of the ROV are colored | |
| 6 | Propellers are protected by nozzles | |

*Fig 22. Primorye Coast Company Safety Checklist*

# Team work

As team work as planning and specialization of labor come to the fore when working on large projects. We have made a Gantt chart before working on the vehicle according to which we have carried out our work. Diagram was altered for several times. It helped us to distribute our efforts correctly and to coordinate mechanical, electrical and software engineers.

*Fig. 23 Konstantin manufactures mission props*

*Fig. 24 Anton debugs ROV control system*

*Fig. 25 Roman solders the Electronics unit covers*

# Reflection

## Dmitry B.

This year became the first for me in the team. I had to face many difficulties and new things. But because of my team and teamwork I was able to learn new things and improve my qualification. After all, teamwork and team relationships play significant role for achieving the best result. This project allows me to increase my level in constructing and 3D modelling, become familiar with a number of new programs for my work. I became more responsible because work of other people depends on your work quality. This project let me to have wider thinking, gaining ideas from different areas. I am very grateful to my mentors and my team for the experience I got. I'm sure that this experience will be very useful for me in the future.

## Denis B.

The first year of my participation in the team became very intense from the very beginning. Firstly, I dealt with organizing and registration of purchasing of necessary materials for the project. It brought me a lot of experience working with documents and communication with sales representatives, accuracy and precision with documents.

Development and production of the whole vehicle subsystem - switching unit - was the new task for I never dealt with. There were a lot of mistakes during solution of this task, which were corrected by joint efforts.

Moreover, teamwork taught me to plan my time, manage it among all tasks, estimate complexity of work. It turned that it is very hard to combine teamwork and personal life.

## Vitaly S.

This year my task was to develop the brain of our system - the electronic unit. Due to this fact I had to combine all systems of our vehicle and make them work properly and synchronously. It was difficult because of necessity of full coordination among all team members. I had to estimate all communication interfaces we have. I got dramatic experience how to create united correctly functional system from several small subsystems. It was very interesting, like to piece together a puzzle.

# Budget

| Items (all values are in $USD) | Re-Used | Actual | Vendor (City) |
|---|---|---|---|
| **Frame** | | | |
| Polypropylene Sheets | | 172 | "Polytex" (Vladivostok) |
| Extruded polystyrene | | 22 | "Prorab" (Vladivostok) |
| Material for all housings (aluminum) | | 766 | "Megamet" (Vladivostok) |
| **Propulsion system** | | | |
| Motor Faulhaber 4490 (6 x $610) | 3660 | | "Microprivod" (Moscow) |
| Material for propellers | 100 | | "StarDV" (Vladivostok) |
| Electronic components for TCUs | 135 | | "Base electronics" (Voronezh) |
| Video system | | | |
| AVC SONY Color EFFIO 960H (2x $190) | 380 | | "Specvideomontazh" (Vladivostok) |
| LED Drivers | | 40 | "Elektromarket" (Vladivostok) |
| **Electronic unit** | | | |
| Power | | 170 | "Elektromarket" (Vladivostok) |
| Microcontroller board TE-STM32F207 | | 109 | "Elektromarket" (Vladivostok) |
| Multiplexer | | 17 | "Omega" (Vladivostok) |
| Depth sensor | | | |
| Pressure sensor | 130 | | "Dalzavod" (Vladivostok) |
| Electronic components | | 2 | "Elektromarket" (Vladivostok) |
| Communication unit | | | |
| Case | | 123 | "Expedition" (Vladivostok) |
| Wi-Fi module | 54 | | "DNS" (Vladivostok) |
| Power source | 530 | | "Base electronics" (Voronezh) |
| Electronic components | | 80 | "Omega" (Vladivostok) |

# Budget

| | | | |
|---|---|---|---|
| **Tether** | | | |
| Hose | | 45 | "Dalzavod" (Vladivostok) |
| Cables | | 127 | "Omega" (Vladivostok) |
| **Payload tools** | | | |
| Rake | | 700 | "Microprivod" (Moscow) |
| Grabber Seabotix TJG300 | 3500 | | "Seabotix" (San-Diego) |
| Components for conductivity sensor | | 14 | "Omega" (Vladivostok) |
| Device for agar sampling | | 50 | |
| **Trip** | | | |
| Airline tickets | | 15800 | Biletur (Vladivostok) |
| Visa | | 180 | The U.S. Consulate General in Vladivostok |
| Customs services | | 1300 | Vladivostokvneshtrans (Vladivostok) |
| Hotel | | 2366 | Days Inn Alpena |
| **Total** | **8489** | **22083** | |

# Acknowledgements

We want primarily to express our gratitude to MATE for so exciting opportunities: to take part in the competition, to see the world and improve our technical skills and interpersonal relationships.

We want to express special thanks to:

- Our mentors, particularly to Alexandr Scherbatuk - our irreplaceable mentor, and to Vladislav Goy who helped us in difficult time sparing neither strength nor time.
- IMTP employers: Denis Mikhailov, Vladimir Kostenko, Nikolai Naidenko for their assistance and patience.
- Our sponsor is FEFU. Without its help we would never participate in this competition.
- Our parents and friends, who reacted to our work with patience and comprehension, and always support us.

# References

1. Analog Interfacing to Embedded Microprocessors/ Stuart R. Ball. 2003, ISBN 978-0750677233.
2. The ROV Manual: A User Guide for Observation Class Remotely Operated Vehicles/ Robert D. Christ, Robert L. Wernli Sr. 2007, ISBN 978-0750681483.
3. Principles of GNSS, Inertial, and Multi-Sensor Integrated Navigation Systems. / Paul D. Groves. ISBN 978-1580532556.
4. "Underwater Robotics: Science, Design & Fabrication" Dr. Steven W. Moore. 2010, ISBN 978-0984173709.