Admiral Nevelskoy Maritime State University

Maritime State University Robotics Team

Vladivostok, Russia

rov Alien ghost

Explorer Class

2014 MATE International ROV Competition
Exploring the Great Lakes: Shipwrecks, Sinkholes, and Conservation in the Thunder Bay National Marine Sanctuary

Members

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Dmitrii Nechepurenko - Second Pilot, Software Engineer (IT security, 2018)
Igor Pushkarev - Software Engineer (IT, 2017)
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Mentors

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Abstract

Maritime State University Robotics Team company is a newcomer to MATE ROV Competition. The company was started in November 2013. To have mission tasks completed we have designed and made a new ROV, named “Alien Ghost”. The vehicle weighs 20kg, its dimensions (length, width, height) are 700x500x415mm and it’s capable of doing the following: sonar scanning, video capturing, measuring shipwreck’s dimensions, entering the wreck, recovering various objects from the seabed, replacing string sensors, measuring groundwater conductivity, collecting samples of microbial mat, etc. It took the company only 6 months (Dec 2013 - May 2014) to have the vehicle developed and the operations team capable of completing all the tasks trained, the estimated budget being USD36,000.

Figure 1. *Left to right:* Kirill Filitov, Igor Pushkarev, Ruslan Revel, Angelina Borovskaia, Nikolai Iatcenko, Katerina Belotskaia, Dmitrii Nechepurenko, Oleg Kozhevnikov, Nikolai Sergeenko

Figure 2. ROV “Alien Ghost” with surface equipment

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Budget

"Don't tell me what you value, show me your budget,
and I'll tell you what you value"
— Joe Biden

Parts, Materials and Miscellaneous

Item	Donations, USD	Expenditures, USD	Provider
ROV			
Surface equipment			
Notebook		700	DNS
TV-tuner		70	DNS
Joystick		70	DNS
TV-monitor		110	DNS
Pelican case		190	Alpha-REK
Mechanics			
Polycarbonate sheet		220	Zenon
Acrylic		35	Zenon
Fittings		140	KIP-Service
Fasteners	100		Marine engineering technology
Materials for housings	140		Marine engineering technology
Materials for props		200	DZL
Electronics			
Microcontroller, debugger/programmer		140	TerraElectronics
DC-DC converters		390	TerraElectronics
Integrated circuit L6201PS ($10 x 10)		100	Omega
Wires		140	Alpha-REK
Connectors		305	Alpha-REK
Video system			
Wide-angle camera		97	SpecVideo
Cameras ($135 x 3)		405	SpecVideo
LED		40	TerraElectronics
Pressure sensor		415	Kipaso
Thrusters ($360 x 8)		2880	RovBuilder
Manipulator		1110	RovBuilder
TOTAL FOR ROV	240	7,757	**7,997**
MISCELLANEOUS			
T-Shirts ($9x10)		90	Interface
Air Tickets ($2080 x 10)		20,800	Biletur
Visa ($160 x 7)		1,120	U.S. Consulate
Accommodations (estimated)		3,890	Hotel
TOTAL FOR MISCELLANEOUS		25,900	**25,900**

Services

Service	Donations, USD	Expenditures, USD	Company
ROV			
Polycarbonate and acrylic cutting		280	Advanced cutting technology
Turning and milling services	560		Marine engineering technology
TOTAL FOR ROV	560	280	**840**
MISCELLANEOUS			
Services of customs declarant		1,110	VladivostokVneshTrans
Printing (estimated)		50	Interface
TOTAL FOR MISCELLANEOUS		1,160	**1,160**

Contributors

Contributors	Amount, USD
Maritime State University	27,500
Agency for strategic initiatives	6,000
Student contributions	1,597
Marine engineering technology	800
TOTAL	**35,897**

By adding up the expenditures for ROV component parts and for material processing services we obtain the vehicle cost at USD8,837. Other expenditures (travel, T-shirts, poster printing, etc.) made up to USD27,060. Thus the project's total budget is USD35,897.

Note: there are no re-used items, as the team is in the project for the first time.

Design rationale

"Design can be art. Design can be aesthetics.
Design is so simple, that's why it is so complicated"
— Paul Rand

Technical requirements to the vehicle

The main purpose of our vehicle is to complete all the tasks proposed by MATE Center, therefore the vehicle has to be able to:

- handle objects in a variety of ways (lifting, grabbing, transporting). This is achieved by mounting a two-degree-of-freedom manipulator and a spiral hook. Apart from that there's a scoop-box at the ROV bottom for collecting discarded bottles from the seabed;

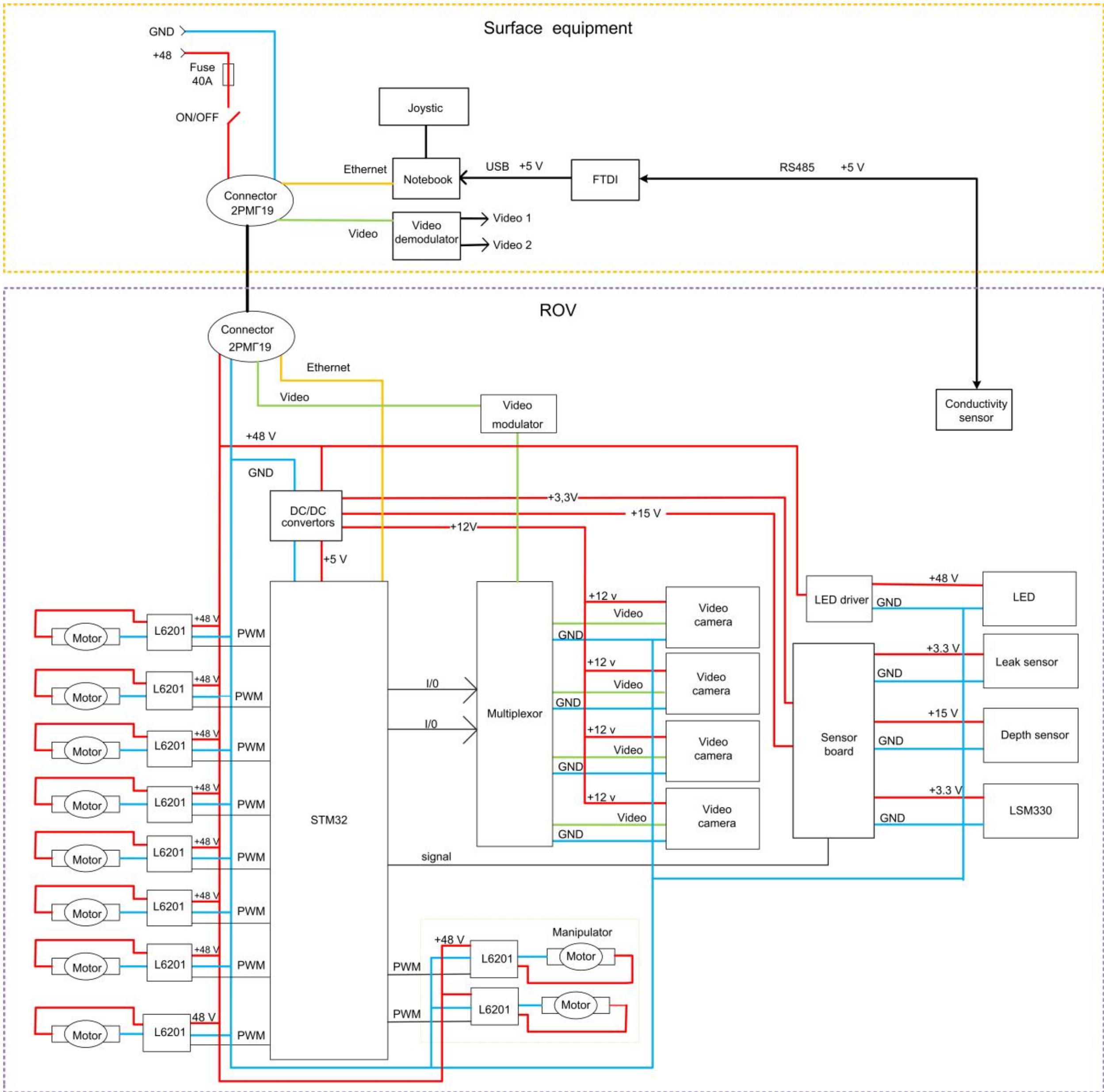

Figure 3. System Integration Diagram (SID)

- lift objects of up to 100N from the seabed. For heavy objects we use a 10kg lift bag;
- measure a shipwreck overall dimensions. The length and the width are measured with a tape, while the height is measured by a depth sensor;
- create images' photomosaic. For this purpose the vehicle is to be accurately positioned as far as its pitch, roll, head, and depth are concerned, and to be fitted with a good camera. Photomosaic is created using certain shareware;
- conduct "sonar" scanning. For this purpose the vehicle is to be accurately positioned;
- collect microbial mat samples. We have made a special mat-sampler for the purpose;
- measure groundwater conductivity. We have made a conductivity sensor for the purpose.

Thus we have equipped our vehicle with the following payload tools:

- two-degree-of-freedom manipulator;
- spiral hook;
- scoop-box;
- lift bag;
- tape;
- mat-sampler;
- conductivity sensor.

Vehicle systems

Frame

When working on the ROV design we would like it to combine possibility of mounting payload and our requirements as to reliability, stability and hydrodynamic properties, as well as to looking smart and unique. Having worked on lots of versions and having drawn a great number of sketches on paper and in SolidWorks we selected a keel-based frame. This version incorporates good hydrodynamic properties, stability, makes it possible to mount all the payload tools, and also refers us to the shipbuilding traditions, thus allowing for transferring the best of shipbuilding practices to ROV building.

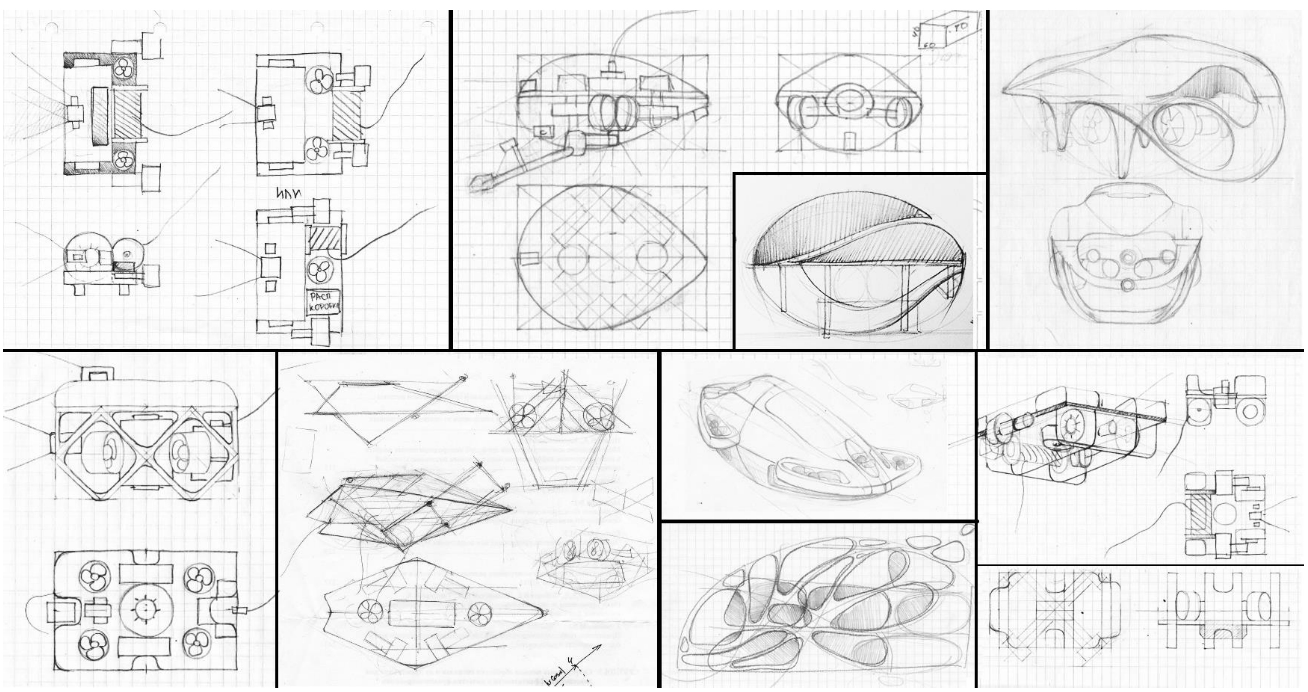

Figure 4. ROV design sketches

The vehicle frame consists of a carrying horizontal plate, a modified keel, and three ribs. All the thrusters, depth sensor, and electronics unit are secured onto the horizontal plate. Cameras, manipulator and other payload tools are mounted on the keel. We decided to make the keel ring-shaped so as to protect the vehicle not only from downwards, but from upwards as well, as the vehicle will have to enter shipwrecks. Ribs will protect the vehicle on its sides; they will also serve as rests and carry lights.

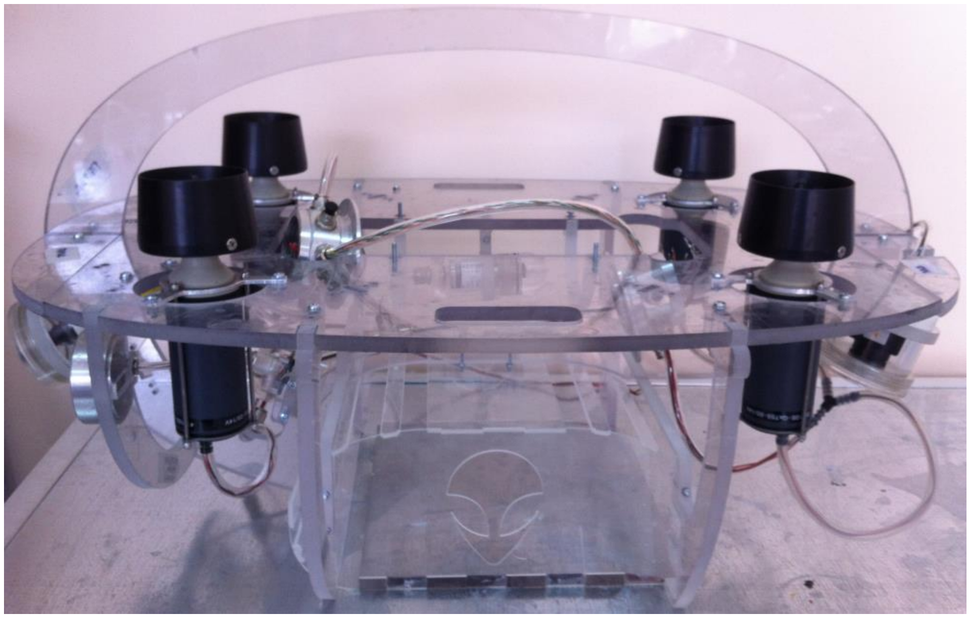

Figure 5. Frame of the "Alien Ghost"

All the elements of “Alien Ghost” housing, including special mounting clamps for the majority of devices are made of polycarbonate (density 1200kg/m^3). Polycarbonate has a high strength, is easily-handled by hand tools and machines, and meets out aesthetic requirements. Polycarbonate cutting was done by a third company using our drawings. Housings for cameras and depth sensor, as well as autopilot and sampler casings are made of acrylic glass. The use of the above materials gives the vehicle transparency, mystique, and similarity to a ghost. And it’s ocean ghosts it will have to deal with when exploring shipwrecks.

The vehicle buoyancy was done by hand from extruded foam polystyrene (density 45kg/m^3).

Figure 6. Thruster

Thrusters

Knowing approximate parameters, weight and required load-lifting capacity of the ROV we have calculated by means of Flow Simulation software the vehicle’s resistance and thrust which should be secured by horizontal (3kgf) and vertical thrusters (4kgf). Then we have analyzed the ROV thruster market. We have compared thrusters of 5 manufacturers regarding their technical data, cost, terms of delivery. Having matched the results of the analysis with our budget and thrust calculation we have chosen a Russian company’s device ROVBUILDER.

The ROVBUILDER’s force is 1.5kgf, when on reverse it’s 1,1kgf. Accounting this we have installed 4 vertical and 4 horizontal thrusters. In the layout of horizontal thrusters we followed that of ROV “Falcon”, which allows for the vehicle’s movements forward/backward, left/right, yawing.

The thruster control boards (TCB) were made by us independently. TCB execute two tasks: they transform 48V surface power into 24V to be consumed by thrusters, and transform control signals into control action.

TCB are made on the basis of integrated circuit L6201P. TCB are located in the electronics unit.

Electronics unit

Electronics unit is the brain of our vehicle. It consists of the main control board, sensor board, power board, multiplexor, video modulator, thruster control boards and leak sensors.

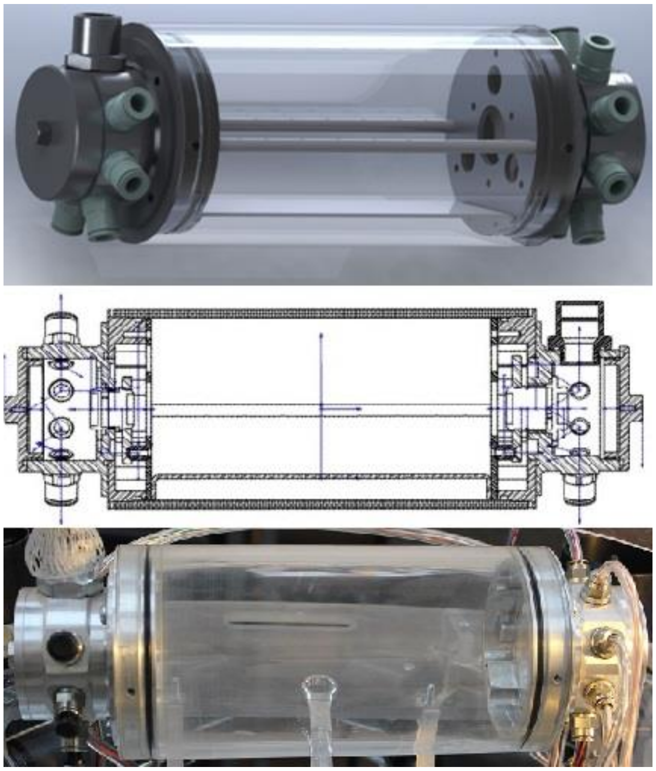

Figure 7. Housing of electronics unit (CAD model, drawing and real assembly)

We have chosen to be the **main control board** TE-STM32F407 a board on the basis of STM32F407 microcontroller. This microcontroller is distinguished for its rapid response and wide periphery. Apart from this we have already had a successful experience in using it, which makes further development easier and faster. The microcontroller executes reception and processing the data received from sensors, controls actuating devices (thrusters and manipulator), calculates controlling and stabilizing signals to thrusters, as well as effected data exchange between Pilot console. The board's voltage is 5V.

To have the signals coming from sensors processed we have developed a **sensor board.** This board processes signals from depth sensor and leak sensors, also it accommodates the main navigation sensor. We have selected to be the main navigation sensor a multi-sensor module LSM330DL with six degrees of freedom. It determines instant acceleration and angles of deflection from central axis. This module has been selected because it is commonly used, it is inexpensive, and possesses good properties: registry of linear acceleration up to 16g, angular velocity up to 2000deg/sec, built-in temperature sensor for its compensation and improved reliability compared to previous models by ST Microelectronics. Voltage consumed by LSM330DL and by sensor board is 3,3V.

We have selected a relative pressure sensor OVEN PD-100, which is usually used for measuring pressure in pipelines to be our **depth sensor**. We have selected it because being inexpensive and relatively small in size the sensor provides for accuracy of to 0.5cm at a depth to 10m. The sensor proportionally transforms the ambient pressure to an electric signal of 4…20mA. The sensor is located in a separate acryl housing specially designed by us.

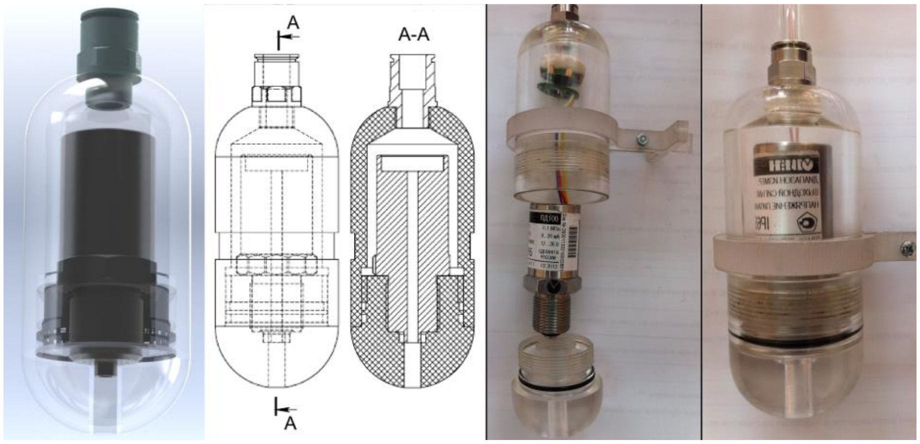

Figure 8. Depth sensor in the housing (CAD model, drawing and real assembly)

Leak sensor is plate with two separated conductors. With water coming between the conductors these are short-circuited, which is detected by sensor board.

We have developed a **multiplexor board**, to have an opportunity to switch video streams from four cameras. This allowed us to use only one coaxial cable to send the video to Pilot console. Multiplexor is based on AD8184 micro scheme, which has 4 video inputs. Digital control of this micro scheme makes it possible to send to the cable the signal precisely from the camera which is needed at this very moment. Multiplexor power supply is +/- 5V.

From multiplexor the signal goes to the video modulator VTU-2/1, which allows us to send 2 video signals at a time. We connect to one channel the front camera and it shows continuously, and we connect to the second channel the output from the multiplexor which switches the data from the other three cameras. Video modulator power supply is 12V.

To have the surface power of 48V converted to voltages suitable for electronics units, sensors and cameras, multiplexor and modulator we have designed a special **power supply board**. Conversion is done through a series of DC/DC-converters. All the converter inputs and outputs are fitted with filters to smooth electromagnetic noise.

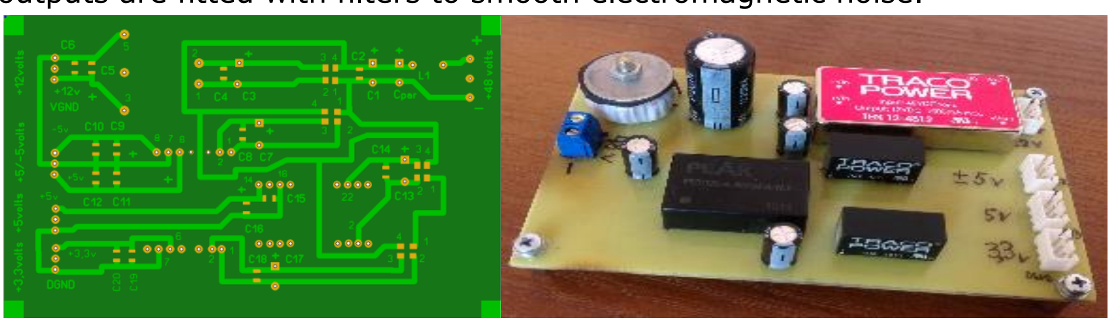

Figure 9. Power supply board (CAD model and real thing)

The board was hand-made (Iron Transfer Method). As the copper film thickness on the textolite is too small, and currents running along the conducting paths are very high the width of the paths was chosen to be as wide as 1.5mm. Also to increase reliability the distance between the paths was chosen to be 1.5-2mm. Due to this high mechanical and electrical reliability of the board was achieved.

On-board control system

Where the frame is our vehicle's body, electronics unit is its brain; on-board control system can be called its soul.

On-board control system executes the data exchange between the vehicle and the pilot console, executes vehicle movements as per the mode set, stabilizes the vehicle with regard to the depth, course, roll, pitch and also effects on-board systems' diagnostics.

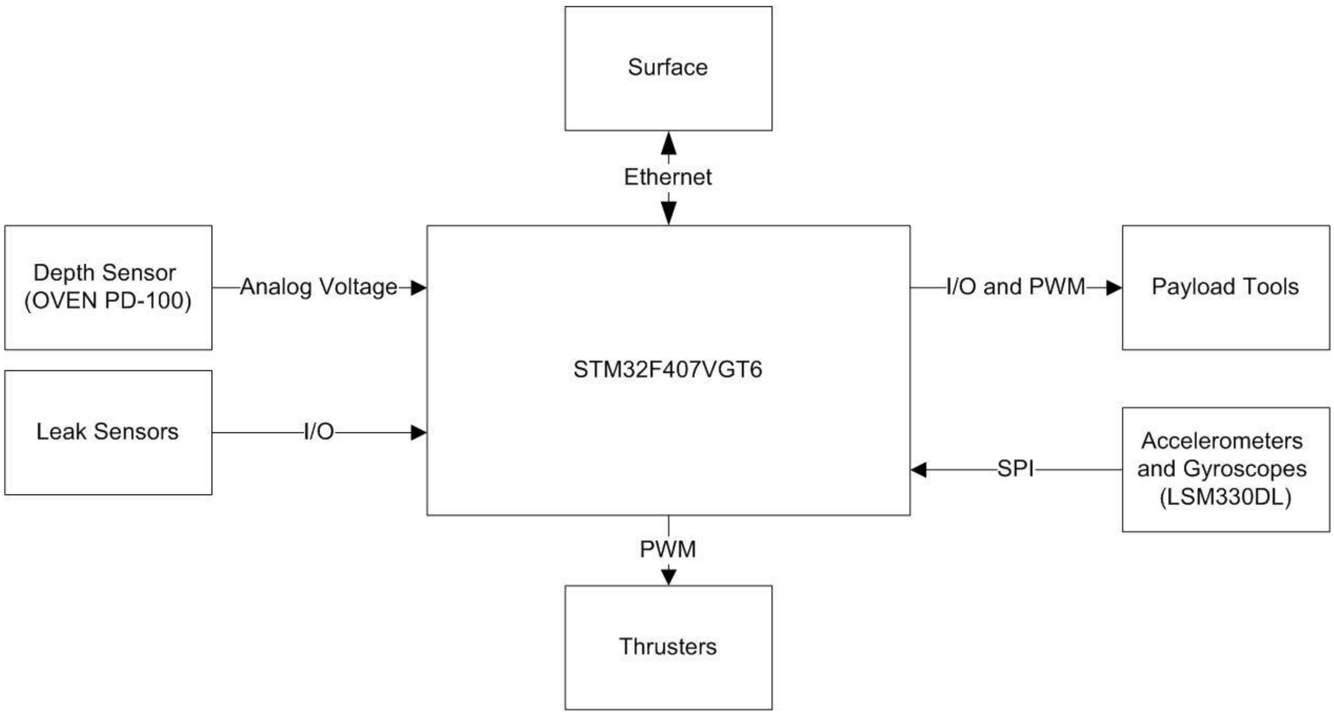

Figure 10. Scheme of on-board control system

As the on-board control system has to execute a variety of functions, respond to the commands given within strictly defined periods of time, and allow for adding up new functions we have decided to use real-time operation system (RTOS). The criteria for selecting a proper RTOS were as follows: it should have been a freeware/openware, installed on the microcontroller we've chosen, be compact, have detailed description for easy getting to work. All the above criteria were met by FreeRTOS, which was our eventual choice.

The program operates on the principle of preemptive multitasking. The top priority task is receiving the data from pilot console. At that reception and processing of data messages, checking its integrity, execution of ‵‵rapid′ commands from actuating devices and recording these into the Receive Structure. Next on the list of priority is Task Regulation, which control vertical and horizontal movements of the vehicle. In these tasks regulator calculation and thruster control signals computation take place in accordance with sensors' data received and pilot commands given. The data are received from the sensors and recorded into Transmit Structure and then transmitted into Task Regulation by ccorresponding tasks Task Sensor. And the least priority task is that of transmitting data to the pilot console - Transmit Task.

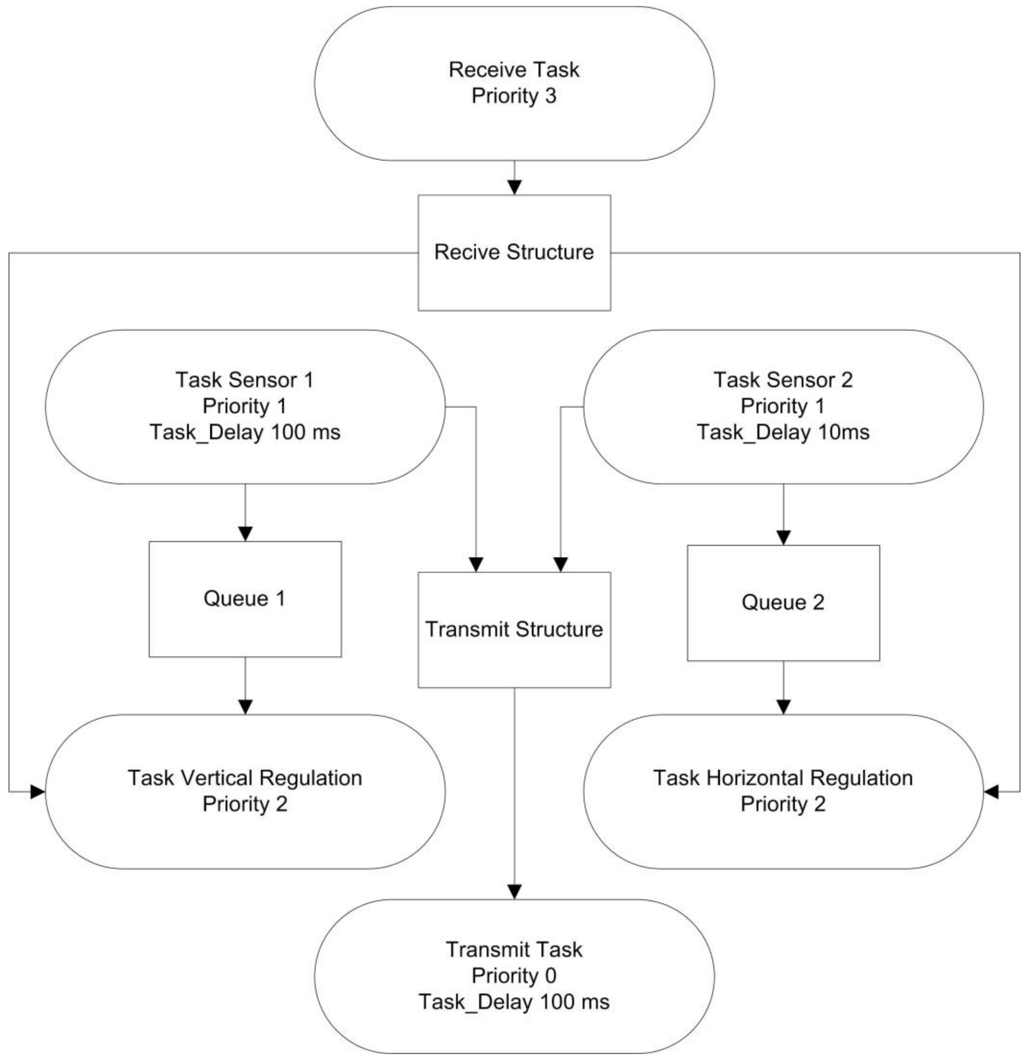

Figure 11. Flowchart on-board software

Cameras

Cameras play ROV's main sensory organ, which serves the basis for controlling the vehicle. That's why cameras must provide view of all the payload tools and necessary surveillance for efficient control. Having tried dozens combinations and reconfigurations we have arrived at a four-camera configuration. The front camera looks straight ahead, the manipulator camera looks onto the manipulator gripper, the middle camera is focused inside scoop-box and the rear camera looks at the entrance of the scoop-box, sampler and tape.

When selecting camera type we were governed by the following criteria: photo sensibility, viewing angle, sizes. For using as the front, manipulator, and middle cameras we have selected an uncased color camera 1/3'' CCD Sony Effio (700TVL, 0,001Lx, 72degrees). The rear camera would require a wider viewing angle, correspondingly we used another uncased color camera 1/3'' CCD Sony (520TVL, 0.5Lx, 72degrees).

We have designed camera containers in SolidWorks, and then we made the drawings and ground them from an acrylic rod on a lathe.

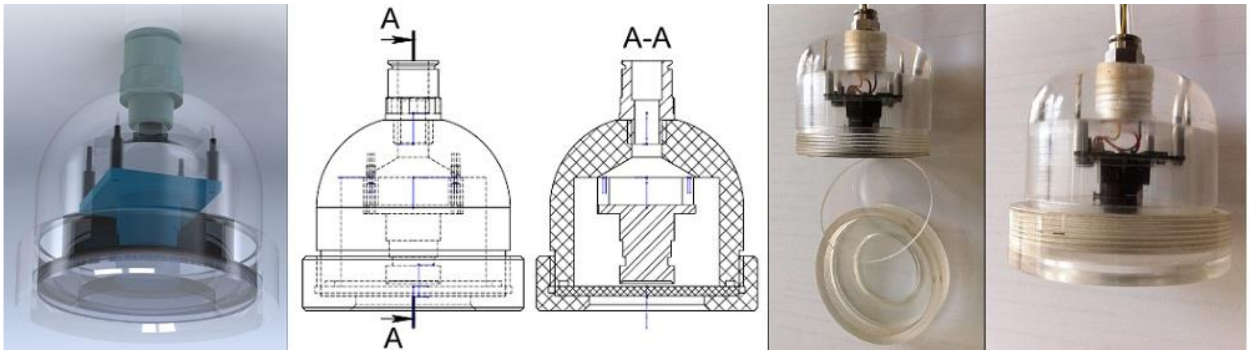

Figure 12. Camera (the front, manipulator, and middle) in the housing
(CAD model, drawing and real assembly)

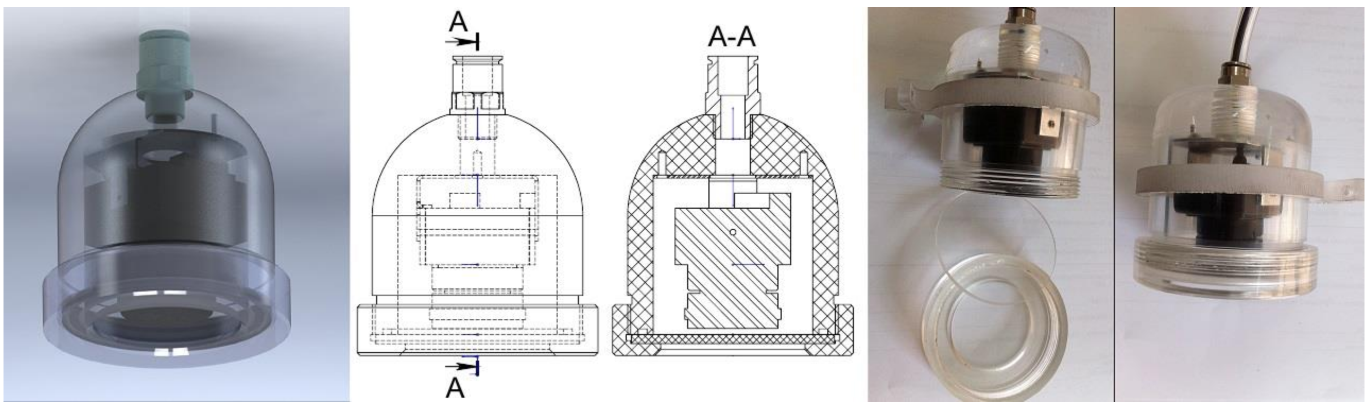

Figure 13. Rear (wide-angle) camera in the housing
(CAD model, drawing and real assembly)

Tether

The tether of our vehicle consists of three constituent parts: a super power supply twin core cable of 4mm: 2 cutset, Ethernet 8-core cable, and transmission line cable.

We have chosen to supply power to thrusters and to boards separately. This would allow for avoiding pulse disturbance for power supply to thrusters from affecting the rest of electronics and secure its stable power supply due to the absence of impact of loss of voltage across thruster power supply cable.

Thruster current consumption can reach 40A.Tthe cable is 20m long. Consequently there'll be loss of voltage across the cable:

$U_{loss} = 2*(L * p * I) / s$, where L-length of cable , p – electrical resistivity of copper, I - current , s – a single core cross section area.

$U_{loss} = 2*(20*0.018*40)4 = 7.2V$.

Power supply to power supply board is done via 4 spare cores of UTP-5 cable (the remaining 4 cores are reserved for Ethernet), and this has been done for the sake of cable simplification and for reducing loss of voltage across it.

Transmission line cable serves for transmitting two modulated video signals from video modulator via demodulator and to the Pilot console.

Surface equipment

Surface equipment consists of a communication unit, two notebooks, and a joystick.

Figure 14. Communication unit

The communication unit serves the following functions: vehicle power supply, power supply source protection from short circuit failure, switching of vehicle, notebooks, TV set (or TV-tuner) and power supply source, presentation of supply voltage and current consumption. At first we planned to build in a notebook into the switch block, but at a later stage we refused it for the reasons of complexity and configured it as a separate unit. The communication unit is a “Pelican” case with AC/DC RSP-2000 converter, SVAL0013NW-100V-E50A ammeter/voltmeter, and VTU-2/1 video signal from vehicle demodulator, placed inside. From the top side tether is connected to the communication unit via jack plug 2РМДТ27КПН19, a notebook, a TV set and/or TV-tuner via jack plug РСГС32. To have outside power supplied one more jack plug 2РМДТ27КПН19 is used. To have the current and voltage reflected an LCD is placed on the front panel. To have the vehicle turned on an automatic tripping circuit-breaker for operating current of 32A is used.

In order to separate the control functions we decided to use two notebooks, the first notebook runs Pilot console programme, and the second one runs Co-pilot console programme for creating images for photomosaic and reflecting the data from the conductivity sensors. Such a solution makes it possible for the first pilot to concentrate completely on priority control tasks, while for the second pilot to carry out additional tasks.

Pilot console is written in C++ language in Visual Studio environment using open source libraries (OpenCV, DirectX SDK).

Communication with a ROV is carried out via Ethernet using UDP protocol. Compared to TCP protocol, UDP is much faster because it will not wait for the delivery confirmation, and as losses across the cable from Pilot console to the vehicle are as little as possible, there’s no need for guaranteed delivery.

The data received from the vehicle are programme-processed and are output into several widgets (roll, pitch, head, angle speed, depth, cameras, leak sensors, and others).

The programme also creates a ROV management pack consisting of such parts as motion control (forward/backward/left/right), the set depth, lighting fixture, roll/pitch stabilizing, etc. The pack is formed on the basis of the data from the joystick and keyboard. The joystick is captured by using DirectX SDK libraries. At that the data from the joystick by-pass the operating system, thus ensuring high speed of vehicle’s operation.

Graphic interface has two modes of work – an ordinary one for controlling the vehicle and for inputting commands, thus simplifying the adjustment procedure.

Co-pilot console as well as Pilot console captures video from vehicle’s cameras. This is done using OpenCV library. Co-pilot console also makes screenshots from cameras and forwards these to Autopano Giga programme for stitching. In the course of selecting a stitching programme, the following programmes were tested: Autopano Giga, PTGui, Panorama Factory. The decision was made on the grounds of quality of the stitched image and stitching speed.

Payload tools

Lights

Under Task 1 the vehicle has to enter a shipwreck and carry out a number of operations there: find a year-of-built plate and lift a plate. As the vehicle has to operate in darkness we decided to develop lights and to install these on the vehicle.

As the light source we have taken two light-emitting arrays Cree CXA2011, with supply voltage of 40V, emitting light quantity of 900lm with current of 270mA. These LEDs require sufficient cooling that's why we made the casing of a single piece of aluminum.

Powerful LEDs require droop circuit; otherwise rapid crystal burnout takes place. As a droop circuit we used a resistor of 36Ohm 7W (per one light emitting array), as the simplest and most reliable solution. PVG612B microchip was used as an electronic gate to switch LEDs on and off, receiving a control signal from the microcontroller board. Both the microchip and resistors are located on a separate board due to resistor heating and for convenient autopilot's configuration.

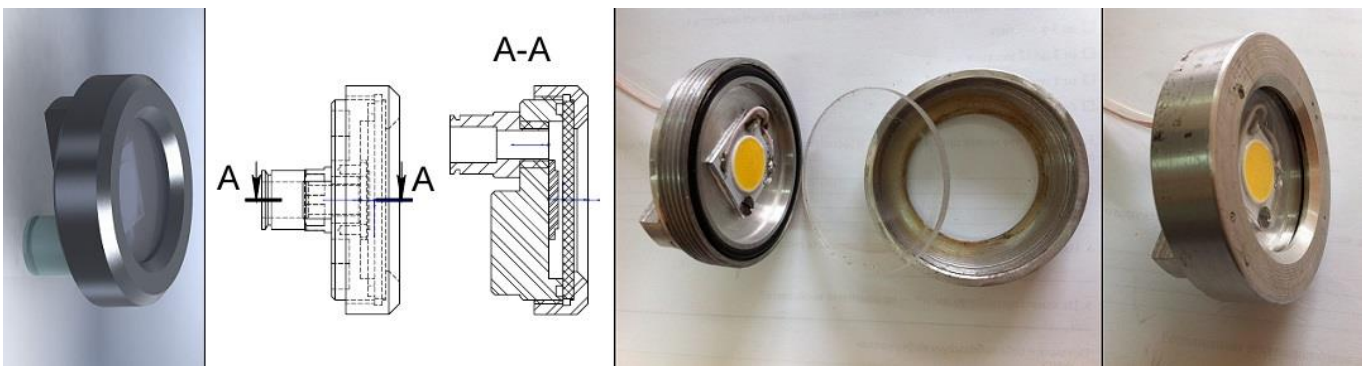

Figure 15. Lights (CAD model, drawing and real assembly)

Conductivity sensor

Under Task 2, the vehicle has to measure water conductivity in a tank. We have developed a conductivity sensor. The nature of the device is simple. You take two stainless steel electrodes, and convey current of sinusoidal waveform of 1kHz frequency to one of them. Correspondingly you take off this signal from another electrode but with the amplitude proportional to conductivity. Afterward this signal is amplified, rectified, measured, and compared to the values, obtained when calibrating and finally obtain the value of conductivity in microsiemens. We use alternating current in order to avoid oxidation of recording electrodes.

We used AD822 operational amplifier as a generator and amplifier. Power is supplied to it via voltage converter 5 to ±5V.

Next step in developing the system was that of transmitting a signal to the notebook. We have chosen to digitize the voltage from the sensor, and send it to the surface by means of RS-485 interface. To have the signal from the sensor digitized and sent to the Pilot console we used ATmega8 microcontroller featuring external reference for ADC and two convertors of MAX485 (UART <–> RS-485) interface and FT232BL (RS-485 <–> USB) interface.

We have chosen to make water conductivity meter completely independent for the purposes of saving time allotted for mission completion, and more accurate measurements. At the very start of the mission we approach the tank with salt water, sink a sensor inside, disconnect it from the vehicle, and proceed to complete other tasks, in the meantime the sensor during a prolonged stay in the liquid to be measured will measure the conductivity as we use a data smoothing algorithm.

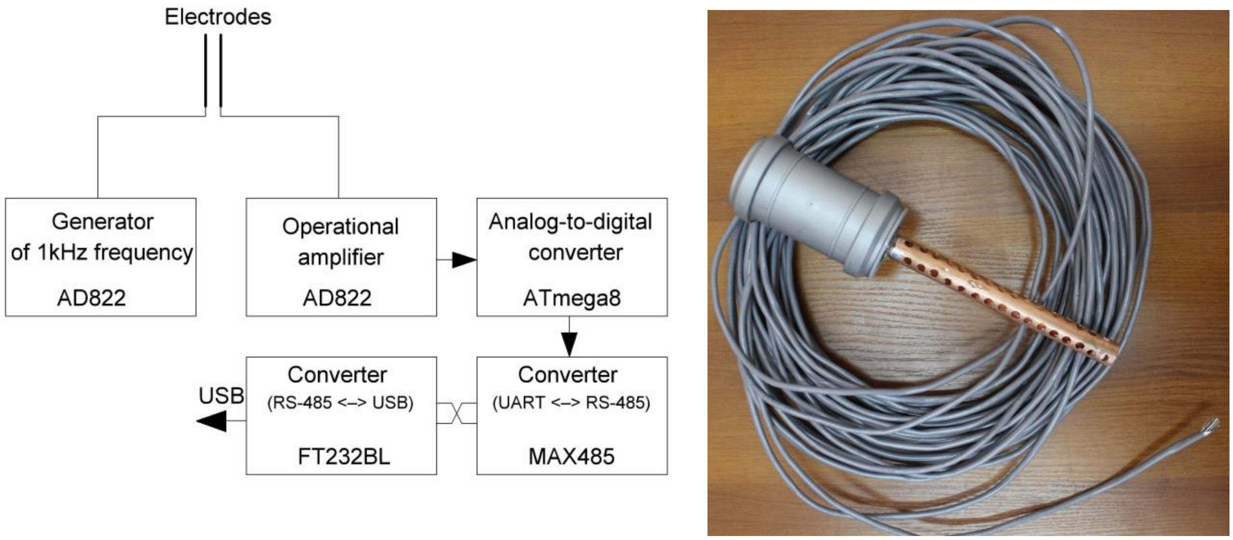

Figure 16. Conductivity sensor (scheme and real assembly)

Manipulator

Manipulator is used practically in all cases when there is a need to grab any object. We use a two-degree-of-freedom manipulator of ROVBUILDER company in our vehicle. Manipulator control board has been developed by us on our own. It is practically the same as the thruster control board.

Figure 17. Manipulator

Scoop-box

It took us long to decide with the help of which device we would collect bottles speedily. There was an idea to use manipulator or design special pinchers, but finally we arrived at a decision to make a box in the bottom part of the vehicle. The vehicle moving backwards would come across a bottle; the bottle would come inside the scoop-box, which it can’t leave thanks to special “shutters”.

Sampler

The design of the sampler is extremely simple. It is just an ordinary acrylic cylinder of the set volume with an inserted plastic tube with notch grooves that would prevent samples from getting outside.

Tape

The shipwreck’s length and breadth are measured by an ordinary tape which is installed in the rear part of the vehicle and which is under the surveillance of the rear camera. The shipwreck's depth is measured on the basis of the depth sensor readings at the level of the shipwreck and on seabed.

Lift bag

To have a heavy anchor lifted from the bottom we use a 10kg lift bag, which is delivered and secured to the anchor by means of manipulator and a latch hook clamped in it. Having been delivered and secured the lift bag would inflate and the vehicle can easily tow the anchor to the surface.

Spiral hook

To have a string sensor grabbed we use a simple spiral hook. We could have used manipulator for the purpose but it is too busy with completing other tasks, therefore to minimize the mission completion time we design such a simple spiral hook onto which a sensor fouls easily and which is easily detachable from the vehicle.

Figure 18. Conductivity sensor, spiral hook, tape and sampler (CAD model)

Troubleshooting Techniques

"Life affords no higher pleasure than that of surmounting difficulties..."
— Samuel Johnson

Our primary method for solving technical problems is as follows:

1) Identify a trouble are and clearly define the trouble;
2) Find the theoretical substantiation for solution. At this stage it is necessary to study manuals, guidance, etc.
3) Find the practical solution through brain-storming;
4) Rectify a problem;
5) Estimate the result.

In practice this method worked as follows.

We initially planned that thrusters would be those of 48V with built-in control boards, but having analyzed and chosen the most accessible and suitable thrusters we chose the ones of 24V and without control boards. That is we had to make our own thruster control boards and at the same time to convert 48V to 24V. As all the mechanical parts had been already made we desperately needed a simple and fast solution to the problem. We studied the ST microelectronics family of microchips for thruster control and stopped at the most suitable L6201PS microchip. By doing this we eliminated the problem of thruster control, but we had to put a limit to maximum voltage at thrusters. We decided to do this by means of PWM – we put software constraints to it on the controller, and hardware constraints by means of comparator circuits within the range of from 25 to 75%. As one thruster is controlled by means of one wire, then with PWM being 25% we rotate at a maximum speed clockwise, with PWM being 50% the thruster is stopped and with PWM being 75% we rotate at a maximum speed anticlockwise. Thus we did it without an extra container with expensive and heavy DC/DC convertor from 48V to 24V.

Overall testing of the vehicle is carried out according to the following algorithm:

1) Check power supply. When the power is supplied lights must burn;
2) Check communications. When wired to the vehicle, Pilot console receives data from it;
3) Check leak sensors. Leak sensors to be closed in turn and received signals are checked.
4) Check thruster system and manipulator. Supply the power to each device independently and monitor its operation correctness.
5) Check video system. Video captured from each camera to be checked independently, switch between cameras' streams to be checked.
6) Check navigation sensors. The vehicle is moved in 3D by a command, sensors to reflect the changes in position.

Safety

"Better safe than sorry"
Proverb

The safety philosophy of our team can be expressed by a phrase "People have a priority over machines". We developed practical safety rules based on this philosophy.

When designing, making and operating ROV we were guided by Germanischer Lloyd's rules of construction, IMCA operating recommendations and looked at Safety Check List by MATE Center. Having scrutinized all these documents we have divided the safety rules into three groups:

1. Rules for safe vehicle construction;
2. Fool-proof requirements;
3. Rules vehicle safe operation.

To ensure safety when constructing the vehicle, we regularly conducted occupational safety briefings.

To meet the requirements for the vehicle to be fool-proof we made use of Safety Check List by MATE Center, enriched by some of our own requirements. As a result our vehicle has acquired its specific safety features of vehicle:

- warning stickers on thrusters;
- fuses;
- LED alarms within the vehicle transparent housing;
- a display on control panel to represent vehicle power supply parameters;

- leak sensors of our own make.

To ensure safety of the vehicle's operation we have made up rules for ourselves and an operating instruction containing pre-start check, procedure for starting-up and operating, monitoring during operation and after- finish check.

Safety Checklist

Pre-start check	√
Check fuse	
Check all connectors and cables	
Check mounts	
Check current and voltage	
Check leak sensors	
Check data from ROV sensors	
Check cameras	
Check thrusters and manipulator	
Check LED	
Monitoring during operation	
Monitoring leak sensors	
Monitoring LED alarm	
Monitoring data from ROV sensors	
Monitoring Current and Voltage	
After-finish check	
Check mechanical damage	
Check all connectors and cables	
Check the structural integrity of thrusters and propellers	

Challenges

"There are no negatives in life, only challenges
to overcome that will make you stronger"
— Eric Bates

Technical

One of the greatest challenges we decided to meet was mastering FreeRTOS real-time operating system and using it on microcontroller. In our previous minor university developments programmes for microcontrollers were small and rather simple for development, thence there was no need to use an operating system. Having set to developing the vehicle we became aware that the microcontroller should perform a variety of functions in a certain consequence and at set times and that it's «correctness» of its operation that would govern the overall functioning of the ROV. The programme for the microcontroller turned out to be flat, complicated, poorly portable and scalable. To get rid of these drawbacks we set a goal of making use a real time operating system.

At first we experienced difficulties in handling RTOS. Due to our small experience many things were not understood and difficult to comprehend. Several times we were even on the brink of quitting the idea. Even OS installation wasn't an easy task. However through planned and step-by-step activities we came to an understanding, the programme started to take on a logical structure and function the way we wanted it to function. Eventually we have mastered FreeRTOS and obtained a well-structured and understandable code. Into which it is quite easy to introduce new functions, as well as to use it in our further developments.

Non-technical

When we decided to make up a team we had no experience, no older mates to help us, no moneys to construct a vehicle and pay for the travel to the competition. In short: no team, no money, no experience.

But we got started. For the beginning we decided to find people in our city who had been experienced in participating in competitions. By doing so we found our future mentors. Then together with them we addressed the university administration requesting some funds for design work and for travel. The university administration believed our mentors and us that we're able to implement the project and allotted some funds. Then together with our mentors we collected 35 students who would wish to participate in the project. Our mentors delivered us an introductory course in underwater robotic engineering and we set to deigning the vehicle. Actually by March there were only 9 team members but these were already not green hands in robotics. And by the end of April a ROV was already finished, and we gained tremendous experience and we made good friends among our mentors and we are ready to take part in the international competitions.

Lessons Learned

"In life, there are no mistakes, only lessons"
— Vic Johnson

Technical

1) We have realized that in carrying out any activity it is the methodology that's essential. At the stage of designing it's sequence of steps and elaborating necessary documentation (sketches, diagrams, drawings, calculations). At the stage of vehicle trials it's trials methods and programme. At the stage of working on the project it's clear split of responsibilities, planning. It is the methodology that helps avoid many errors, non-coordination among the designers and considerably reduce the development time. Unfortunately we understood all the said only after we had done lots of mistakes, encountered technical non-coordination and wasted lots of our time.

2) We have learnt how to work with CAD means, such as SolidWorks, AutoCad, Altium Designer, etc.

3) We have learnt to independently make printed wiring cards using Iron Transfer Method. Using only Laser printer, glossy paper, Copper PCB boards, An iron, Etchant ($FeCl_3$) we have been able to make virtually all printed wiring cards for the vehicle (power supply board, TCBs, LED driver boards, conductivity sensor board).

4) We have learnt how to solder SMD components.

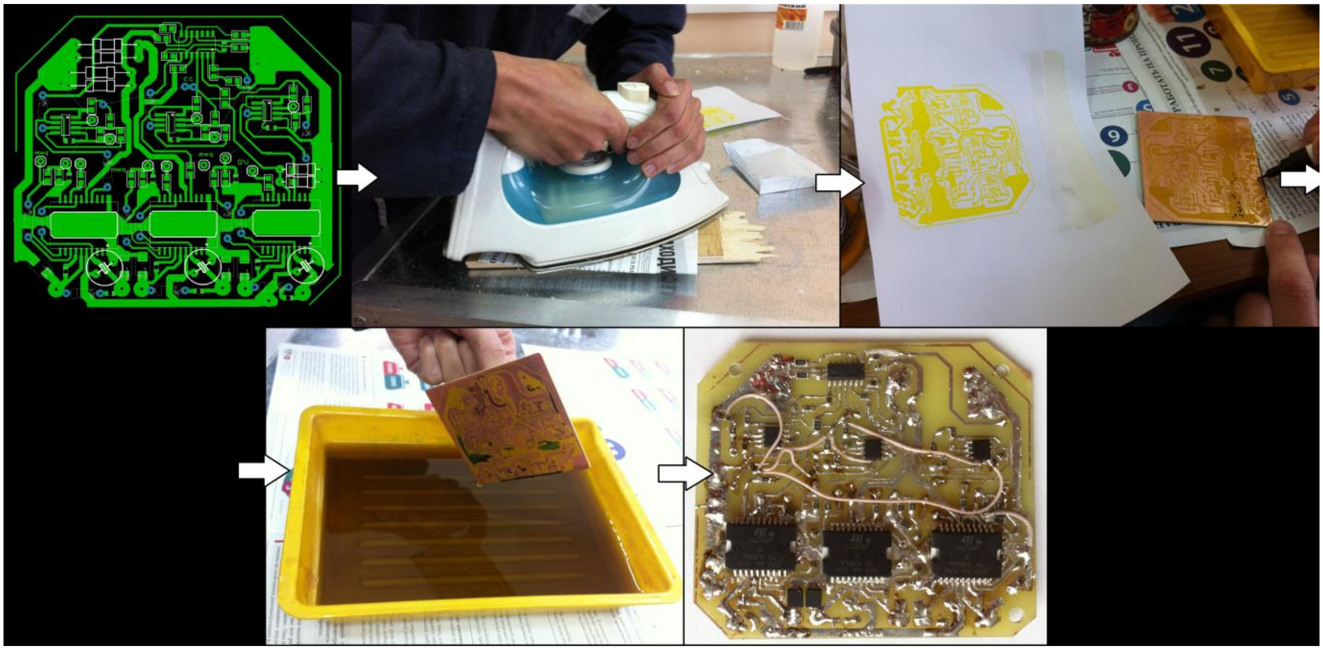
Figure 19. Making TCB by Iron Transfer Method

Interpersonal

As we are an overseas team to get to the USA for competitions we need traveler's passports and US visas. Right from the beginning our mentors insisted that we have our traveler's passports issued (in Russia a passport issuance procedure can take up to two months). We somehow neglected their advice. And when in February we went to buy tickets for flight to the USA we found that the travel agency can't sell tickets to those of us who had no traveler's passports. Then there was a rush in urgent applying for passports' issuing, and when we eventually received these in April only inconvenient flights at a price much higher than in February were available.

We have learned two important lessons from this. First, never neglect a piece of advice from a more experienced mate. And second, that all the processes within the project need to be managed. We failed to manage the passport receiving process, regarding it being something trifle, and we paid through the nose!

Future Improvement

"If you do not think about the future, you cannot have one"
— John Galsworthy

This time we have designed and made all the systems by ourselves, with the exception of thrusters and manipulator. We have to admit it was a real problem to purchase ones. The prices are rather high for the purposes of our project, while terms of delivery tend to be unreasonably long. This year we were virtually saved by ROVBUILDER company. Bearing the said in mind we're intending to develop thrusters and manipulator on our own next year. A thruster is thought to operate at 48V and to be controlled via an interface suitable for us. As a result we're planning to cut the vehicle production cost and to have our professional skills considerably upgraded.

Reflections

Angelina Borovskaia

I've been in the MATE competitions for the fourth time. I have learnt much during this period of time: how to design ROV, to lead a team, to make posters and technical presentations, and a lot of other things. Thanks to experience gained in the team I was even invited at the end of last year to work for a local company engaged in ROV development. Thus this year I've had to combine studies, work and work on the project. Also this year I was held fully responsible for the vehicle design without mentors. I felt all the burden of responsibility, but that also allowed me feel grown both as a designer and a personality.

Kirill Filitov

Before I joined the team my experience as a designer was limited to construction of small and rather simple models aircrafts in my home workshop. When I became a member of the team I realized that a serious project would need a serious attitude in everything: thorough designing of separate unites and components using sophisticated software such as SolidWorks, AutoCAD, detailed scrutiny and adjustment of separate components to each other, elaborated search for solution to complex engineering problems. It was new to me to work in a team of people, who, like me, were keen on one task – building a vehicle.

Katerina Belotskaia

Before I came and joined the robotics team the projects I'd been engaged in were purely mine. I couldn't let no one down but myself, if for instance I failed doing anything according to a plan. And this has virtually become my first teamwork. It turned out to be difficult: a lot of responsibilities, the previous principles of work when I had been all on my own would not work. And this experience was for me of more value than the knowledge and practical experience gained in constructing the vehicle. It is not easy to learn how to work fast and in accord with unknown people, how to overcome your laziness, how to set the priorities, to allocate the time, etc. You can't learn all these things from books, you need to feel it yourself and get one's share of frustrations and winnings.

Dmitrii Nechepurenko

This is the first time I participate in a serious project. It is thanks to him that I've learnt much new about programming, learnt to apply my theoretical knowledge in practice, find solutions to real problems, got acquainted with numerous useful libraries and programs. But the most important thing, that was a discovery for me is teamwork. I understood that despite extra responsibilities it is easier and more interesting to work with like-minded people. You are motivated to do everything faster and better than when you are on your own.

Oleg Kozhevnikov

Due to the project I realized in which functions I am better and in which worse. The main function that I had to master was multitasking. Starting from the very first days of work I more and more departed from academic classes at the university and became engulfed into practical robotics engineering, as well as to my dream – a travel to America. It should be noted that the knowledge I obtained when doing practical work was much more valuable than that gained through sitting in a lecture-room. I also learned a fundamental thing – understood the logic of designing an electronic device from scratch.

Ruslan Revel

I have always had likeliness to robotics engineering. When I was offered to take part in the project I gave my consent on the spot. Following my curiosity and wish for something new I chose circuit engineering as my field of study. There were many failures at the beginning. But thanks to hard labor and to advice on the part of my mentors, teammates understanding came even in this sophisticated area of activity.

Iatcenko Nikolai

Prior to participation in this project I had no experience in teamwork, as well as my skills in making electronic devices weren't rich. Therefore taking part in making the vehicle was a very powerful stimulus to improve my knowledge in electronics, so that not to lag behind the team and not to let the teammates down. Teamwork turned to be of utmost interest, where people are keen on making a robotic diver and not only for the purpose of going to competitions, but to make their ROV the best one. As for me participation in such most interesting teamwork disciplined I learnt much new about circuit engineering and learnt the basics of designing electronic devices from scratch. Also I received an invaluable experience in independent circuit-board work.

Teamwork

"Alone we can do so little; together we can do so much"
Helen Keller

We believe that practically any aim can be achieved if you have a good team and a well-thought plan, that is why we started our work with making up a Gantt Chart and distinct task allocation we could rely only upon teamwork members, as our mentors are employed not only at the university, and therefore are very busy. We've split into three groups: designers, electronics engineers and programmer. Within each group a person in charge was determined to arrange for the activities within the group. There was always been a division of leaders. CEO was responsible for the project as a whole as well as for interaction with mentors. CFO was responsible for financing and purchasing, CTO was responsible for manufacturing, while CAO was responsible for interaction with the university administration.

To have the progress of the project tracked we used a free online Task Manager Producteev. This freeware let every team worker a chance to track the course of the project tasks, set priorities to the tasks and jointly solve the tasks over distance.

	ℹ	Название задачи	лительност	Начало	Окончание	Названия ресурсов
1		Props	30 дней	Пн 02.12.13	Пт 10.01.14	Filitiv
2		ROV	**116 дней**	**Пн 02.12.13**	**Пн 12.05.14**	**All**
3	✓	**Design**	**100 дней**	**Пн 02.12.13**	**Пт 18.04.14**	**Borovskaia**
4	✓	Designing	35 дней	Пн 02.12.13	Пт 17.01.14	Borovskaia;Belotskaia
5	✓	Purchase of materials	30 дней	Пн 17.02.14	Пт 28.03.14	Revel
6	✓	Manufacturing	25 дней	Пн 10.03.14	Пт 11.04.14	Filitiv
7	✓	Assembling	5 дней	Пн 14.04.14	Пт 18.04.14	Borovskaia
8	✓	**Electronics**	**100 дней**	**Пн 02.12.13**	**Пт 18.04.14**	**Kozhevnikov**
9	✓	Designing	53 дней	Пн 02.12.13	Ср 12.02.14	Kozhevnikov
10	✓	Purchase of materials	32 дней	Ср 15.01.14	Чт 27.02.14	Revel
11	✓	Making (soldering)	30 дней	Чт 13.02.14	Ср 26.03.14	Kozhevnikov;Iatcenko
12	✓	Testing	17 дней	Чт 27.03.14	Пт 18.04.14	Kozhevnikov;Iatcenko
13	✓	**Software**	**100 дней**	**Пн 02.12.13**	**Пт 18.04.14**	**Nechepurenko**
14	✓	Software design	25 дней	Пн 02.12.13	Пт 03.01.14	Nechepurenko
15	✓	Programming	43 дней	Пн 06.01.14	Ср 05.03.14	Nechepurenko
16	✓	Debugging	32 дней	Чт 06.03.14	Пт 18.04.14	Nechepurenko
17	✓	Assembling	8 дней	Пн 21.04.14	Ср 30.04.14	Borovskaia
18	✓	Debugging	8 дней	Чт 01.05.14	Пн 12.05.14	Kozhevnikov
19		Creating a demo video	4 дней	Вт 13.05.14	Пт 16.05.14	Revel
20		Technical report	39 дней	Ср 19.03.14	Ср 28.05.14	All
21		Poster	25 дней	Пт 25.04.14	Пт 13.06.14	All
22		Engineering evaluation	15 дней	Ср 28.05.14	Ср 18.06.14	All
23		Training in the pool	21 дней	Пн 19.05.14	Пн 16.06.14	All

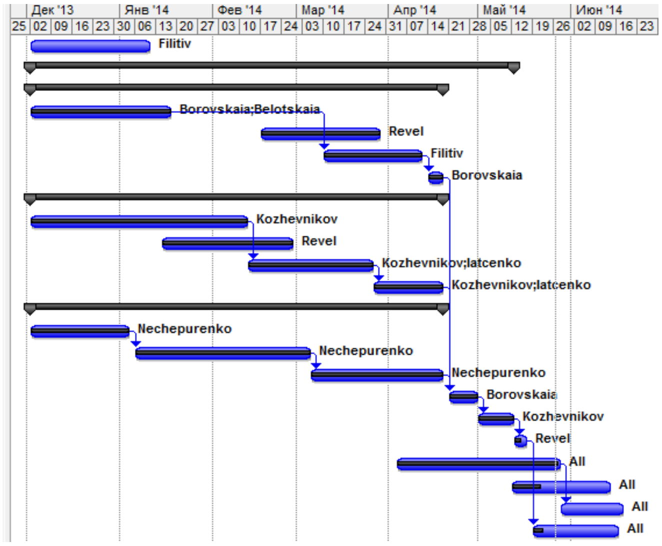

Figure 20. Gantt Chart

Figure 21. Angelina and Kirill are making the buoyancy

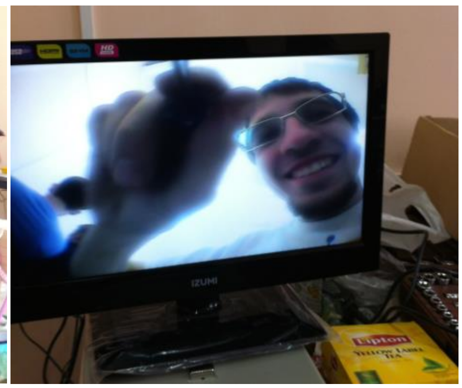

Figure 22. Nikolai is adjusting the camera's focus

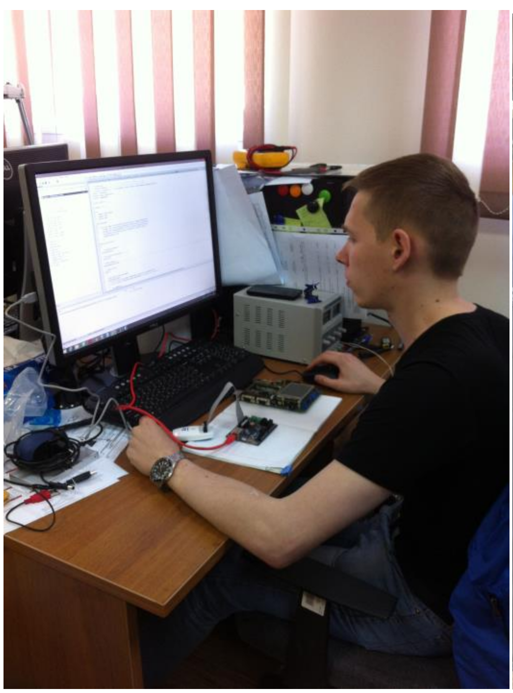

Figure 24. Igor is programming the microcontroller

Figure 23. Oleg and Nikolai are soldering boards

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