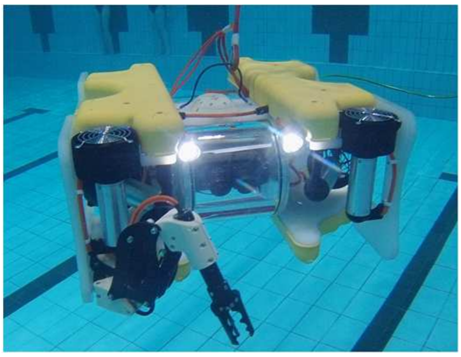
MATE International ROV Competition 2013, Explorer Class

Bauman Moscow State Technical University | Moscow | Russia

Technical Report



Akvator-3D ROV

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It's the fourth time the BMSTU team is participating in the MATE competitions. The students of the Underwater Vehicles Department of the Bauman Moscow State Technical University represent the main part of the team. This year our company presents a work class ROV "Akvator-3D" designed for performing mission of the 2013 MATE Competition.

The "Akvator-3D" propulsion system consists of 4 vertical thrusters and 4 vectored horizontal thrusters. The thrusters of our ROV are designed by our company. Our ROV has a high repair capability in field conditions as a result of modular electronics structure and special features of pressure hulls and its frame.

The ROV is equipped with 4 cameras (2 of them are united in 3D-vision system).

The company designed a shore control station. Heading, pitch, roll and depth stabilization systems, the top-quality GUI and the 3D-vision system simplify the ROV-Pilot's job. All control systems were programmed in C and Processing.

We created a 4-function hydraulic manipulator instead of the multiple payload tools designed for accomplishing the mission tasks. We developed a payload tool for adjusting the legs of the secondary node.

We designed an optical beam transmissometer as an independent module.

This year our team has paid more attention to the problems of the ROV and workspace safety

Besides solving the complicated technical tasks our team also dealt with the project management problems. We took measures to optimize the project management process and created a solid team of the ROV builders.

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After receiving this year competition tasks our team discussed and made decisions about the structure of all our ROV systems and defined the technical tasks for this year.

In view of the great amount of installing, transferring, pulling, etc. subtasks our company arrived to a conclusion of the 4-function electro hydraulic manipulator necessity for our ROV.

The measuring distance subtask was decided to be performed with using a Video Length Measuring System (VLMS).

We decided to create a special payload tool based on servo motors for realizing the operation of adjusting the secondary node legs.

We made a decision to construct a transmissometer unit based on the photoconductive resistor. We decided to display this data on a tablet PC.

As a matter of our team experience of participating in the MATE competition and the specificity of this year mission we formulated the next problems for the ROV design:

- **SAFETY!**
- High repair capability in field and “lack of time” conditions;
- High maneuverability, rapidity and high carrying capacity;
- The ROV should have user-friendly and top-quality control systems. Indeed as fast the ROV Pilot completes all the tasks the more chances for winning the competition we have!

The sketch clarifying the ROV systems work is presented in Fig. 1.1

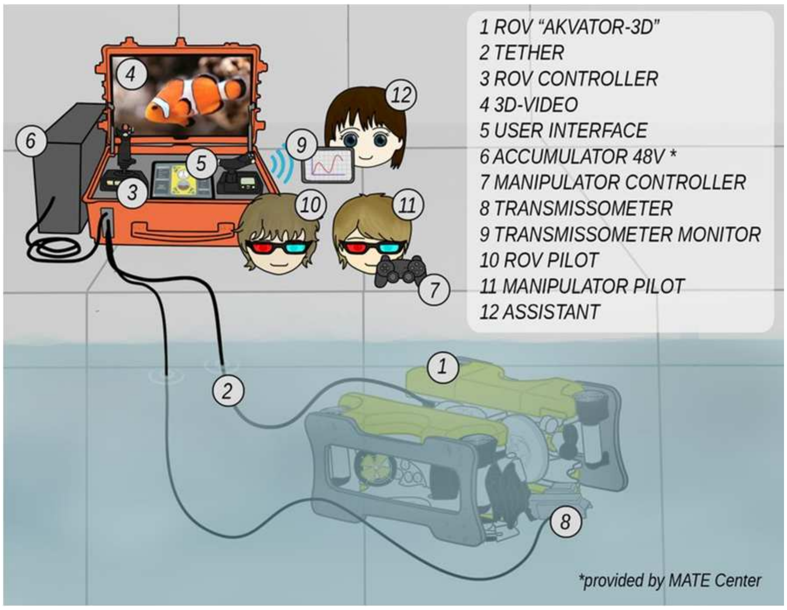


Fig. 1.1 The Sketch of the Akvator-3D suite

1.1 Frame

The Akvator-3D’s frame (Fig. 1.2) is made of the 15mm thickness leaf polypropylene. This material was chosen because of its hardness, toughness and 10%-positive buoyancy. As the result of the hydraulic cutting technology of its treatment the frame has a smooth and complicated form . The frame construction optionally has convenient handles for carrying the ROV, loops for transporting the ROV by means of the winch, a group of holes for additional payload tools and special bracings for the cable taking the weight from the sealed connectors.

Akvator-3D design concept!

We wanted our ROV to be repairable, hence we wanted it to be properly designed for assembly and disassembly operations.

The Akvator-3D's frame is to be assembled with only 8 screws!

It was designed in such a way that allows to put the ROV on 4 of its 6 faces providing the convenient access to the ROV electronic and mechanical systems.

"Safety comes first!"©

As a result of the hydraulic cutting technology treatment all the frame edges are smoothed out. There are no sharp corners in the frame construction that eliminates the risk of hurting someone.

1.2 Buoyancy

The Akvator-3D's buoyancies are made of polyvinylchloride foam PS-1-150. This material saves its qualities on 150m depths.

The buoyancy parts are covered with special protecting covers (Fig. 1.2). All the tethers and balancing weights are hidden under these covers.

Fig. 1.2 The Akvator-3D buoyancy and frame

1.3 Propulsion System

The propulsion system of our ROV consists of 8 thrusters that were designed by the company engineers and were based on the 150W MAXON (RE 40) collector DC motors. Each DC motor was installed in a seal aluminum housing and rotates a 2 blades propeller through the longish shaft. The shaft was sealed with 2 armored collars. The cavity between the armored collars was filled with silicone grease. The propeller was ducted in special faring that increased the propulsion power. The propeller duct was made on a 3D printer.

The thrusters of our ROV (Fig. 1.3) develop around 25 N of thrust each at 48 Volts with an average current draw of around 1.5 Amps. Our company has been using these thrusters since last year. We slightly modernized them this year.

Fig. 1.3 Akvator-3D thruster

Our ROV has 4 vertical and 4 vectored horizontal thrusters (Fig. 1.4). Such placement of thrusters produces a high maneuverability for our ROV in 6 degrees of freedom and high payload capacity.

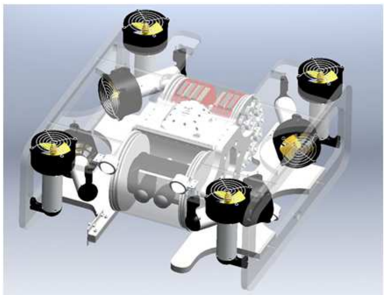


Fig. 1.4 Akvator-3D thruster placement

"Safety comes first!" ©
The gratings, installed on the both sides of the thrusters, eliminate the possibility of something falling into the propeller and make the unit safe even for children.

1.4 Pressure Hulls

Electronics Pressure Hull

The pressure hull for the electronics unit consists of a 180mm diameter Plexiglas's tube and 2 aluminum endcaps with O-rings and sealed lead-in connectors (Fig. 1.5). 12 developed by our company sealed connectors are located on each endcap. Transparent sides of such a pressure hull permit to check the ROV electronics systems before turning the power on or plunging the ROV. The aluminum endcaps load the construction but help to solve the problem of DC/DC convertors cooling.

Fig. 1.5 Electronics pressure hull

Akvator-3D design concept!
The pressure hull for the the ROV electronics is to be assembled without any screw! When the pressure hull is mounted on the Akvator-3D, the ROV frame fixes the hull endcaps preventing their depressurization.
In the setup mode it is possible to install the electronics unit on the ROV without the Plexiglas's tube, hence you have a free access to the ROV "heart" and "brain"!

Fig. 1.6 The video system pressure hull

Pressure Hull for the Video System Unit

The video system pressure hull (Fig. 1.6), is identical to the electronics pressure hull. This decision reduces the list of necessary replacement parts. The main difference between these hulls is an amount of the sealed connectors in endcaps (in the video system pressure hull there are 3 of them) and the existence of the fixtures for a cameras rotary mechanism in video system's hull.

The mechanism allows ~160^0 rotation angle, that permits to obtain a vertical prospect view of the robot surroundings

Fig. 1.7 The hydraulic system pressure hull

Pressure Hull for the Hydraulic System Unit

The most outstanding result of this year is the hydraulic system of our ROV. It consists of the hydraulic power unit with the underpressure valve that is tuned to 10 bars pressure value and the control valve box (Appendix 2). All these parts are placed in a special pressure hull (Fig. 1.7) that is located between the electronics and the video system pressure hulls, in the center of our ROV. This unit makes it possible to control 3 hydrocylinders. Hydraulic fluid consumption of our system is about 350 mL/min. The hydraulic fluid for our system is a biodegradable food-grade fluid.

Safety comes first! ©
The components for our hydraulic system were bought in Leimbah Modellbau company and conform competition's rules.

Sealed Connections

There are 28 sealed connections in our ROV. All these sealed lead-ins and lead-outs were developed by our company! We developed 4, 7 and 10 pin connectors. Each female connector is infixed in 22 mm hole in endcap and is fixed from within via lock collar.

The O-ring in each male connector provides it seal ability. The special hold-down nut is used for the further connector fixating.

Fig. 1.8 Sealed connectors

Safety comes first! ©
The special colored sticker is attached to each of sealed lead-in and lead-out of our ROV. The function of the connector is presented on its sticker (Fig. 1.8).

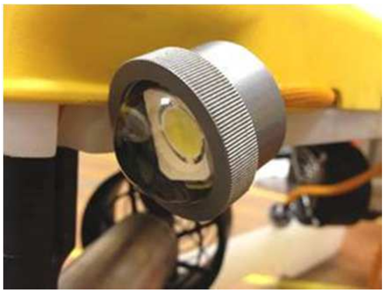


Fig. 1.9 Akvator-3D light

1.5 Lightening System

The Akvator-3D is fitted with 4 20W LED flashlights. Two of them look forward direction and the remaining 2 illuminate the bottom under the ROV. We use High-Brightness LEDs in the Akvator-3D's lightning systems. These LEDs have high heat generation so the pressure hull of LED is filled with biodegradable food-grade oil.

The glass of the light hull has a convex, lens-shaped configuration (Fig. 1.9). It dissipates the light perfectly and lightens the working space equably (Fig. 1.10).

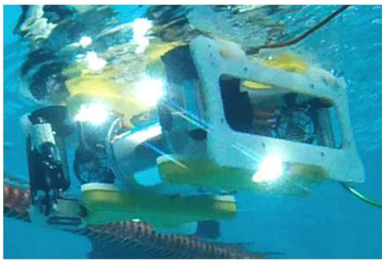


Fig. 1.10 Akvator-3D lights

2. Electronics

2.1 Tether

The Akvator-3D tether consists of 30 thin connectors and 2 thin coaxial cables that are spaced in safety braid. Each connector length is 20 m. Each of 20 power connectors has 0,35 mm^2 cross-sectional area. Each of 10 signal connectors has 0,12 mm^2 cross-sectional area. Two of the signal connectors were reserved for RS-485 data channel, 4 of them were reserved for analog cameras and the rest of 4 connectors is not in use nowadays but they can be used if we decide to increase the ROV functionality or they can be used as a back-up in case of other connectors damaging. Two coaxial cables were meant for image transmission from the main ROV cameras in HD-SDI format. The cable is supplied with buoyant torsion balances. Such construction provides the high figurability and breakage resistance.

2.2 Power Supply Board

The Akvator-3D supply voltage is 48V. Total ROV power consumption is limited by 2kW. That is why 40A safety fuse is used. The ROV power electrical schematic is presented in (Fig. 2.1).

The power supply board (Fig. 2.2) includes three DC-DC converters. Two TEN-40-4811WI units convert 48V to 5V and SMB60 converts 48V to 12V.

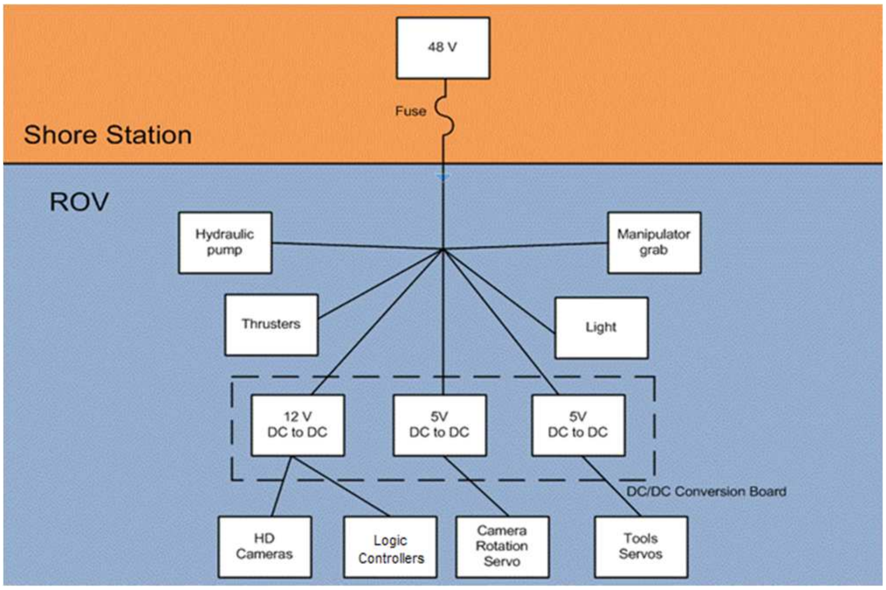


Fig. 2.1 Akvator-3D's electrical schematic

2.3 Thrusters Control Board

To drive the Akvator-3D thrusters we use eight Pololu 20 A high-power motor driver units. To increase repairability these drivers are mounted in separate sockets on the thrusters control board (Fig. 2.3). This way we can easily replace them in case of a failure. There are two Arduino Pro Mini units installed on the board, each one controls 4 of 8 drivers. They are known as Vertical Thrusters Controller and Horizontal Thrusters Controller.

Fig. 2.2 Power supply board

Safety comes first! ©
Each Pololu driver unit has a built-in short circuit and overheating protection. Besides, we can monitor motors current via drivers current sensors. High motor current can tell us that the thruster is blocked and needs to be stopped. Therefore, Thrusters Controllers are programmed to shutdown the motor when its current exceeds 4 Amps.

Fig. 2.3 Thruster control board

2.4 Communication Controller Board (CCB)

This board consists of a Seeeduino Mega unit based on Atmega1280 microcontroller, USB-hub with 7 output ports and USB signal amplifier (Fig. 2.4). Seeeduino Mega unit is known as Communication Controller as it manages all the interconnections of the ROV.

It receives and transmits data via RS-485 (ROV-Shore) data channel and distributes data between ROV microcontrollers via I2C data bus.

Aside from that, Communication Controller receives and processes data from Vectornav VN-100 orientation sensor. Use of USB-hub with USB signal amplifier allows us to update the ROV firmware without dismantling it. Full communication systems diagram is presented in Appendix 1.

Fig. 2.4 Communication controller board

2.5 Equipment Control Board

The main part of this board is the Equipment Controller. It is connected to the I2C bus which is used to receive commands from the Communication Controller. The main purpose of the equipment controller is to form control signals to all of the equipment mounted on the vehicle. There are three Pololu-20A drivers on the board. They are used to control LEDs, hydraulic pump and DC-motor inside of the manipulator grab. These drivers are easily removable modules with special male connectors. They have built-in current sensors, which allow equipment controller to manage the force of the grab and also track any electrical circuits malfunctions.

A connector for the depth board is also placed on the equipment board (Fig. 2.5).

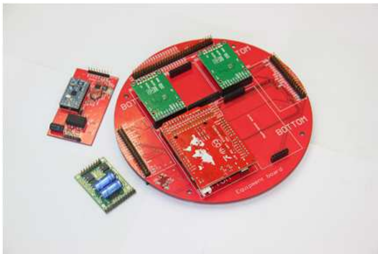


Fig. 2.5 Equipment control board

2.6 Depth Sensor Board

The depth sensor used in the vehicle is based on the strain gauge pressure transducer. The depth sensor board, which takes care of the signal processing, is designed as a detachable module on the equipment board (Fig. 2.5). This approach allowed us to conduct a series of experiments with different signal processing circuits. In future it will facilitate our work on upgrading and repairing the vehicle.

Fig. 2.6 Electronics unit construction

Safety comes first! ©
Safety features of the Akvator-3D electronics:

- All additional connectors placed on the boards are asymmetrical and have different shapes (Fig. 2.5). That makes it impossible to mix connectors or plug detachable modules the wrong side.
- Fuse in the 48V power circuit protects electronics from damage in case of a short circuit.
- Modular implementation of the main electronic boards allows user to successfully assemble system of any required structure. (Fig. 2.6)
- All voltage converters used in the vehicle have short circuit protection.
- Humidity sensor inside of the electronics housing is able to monitor even the slightest changes in the humidity value. If the value exceeds the dangerous level, it triggers alarm.

2.7 Orientation Sensor

For the ROV orientation our Company uses VectorNav VN-100 sensor (Fig. 2.7). In the AHRS (Attitude Heading Reference System) mode sensor provides us with the heading, pitch, roll, angular velocities and linear accelerations data which is used in the ROV stabilization systems. The sensor is mounted in a special pressure hull on the top of the ROV frame (Fig. 2.8)

Sensor sampling frequency is about 100 Hz.

Fig. 2.7 VN-100 orientation sensor

2.8 Video System

The Akvator-3D video system consists of 4 ROV cameras and 2 surface control unit monitors. Two Full-HD MDC-H4290CTD cameras are situated in the rotary mechanism of the video system pressure hull and are united in the 3D-Vision system. The cameras output signals are in HD-SDI format. These signals are transmitted to the SCS via coaxial line. In SCS the signals are converted and punched up on the stereo display.

Also the ROV has connectors available for two PAL cameras that could be added in case of working with payload tools that are located out of main cameras sight. Their signals can be transmitted to the SCU via twisted pairs.

Fig. 2.8 Pressure hull of the orientation sensor

3. Control System

3.1 Graphical User Interface (GUI)

The Akvator-3D GUI is presented on a smaller auxiliary screen at the SCS (Fig. 3.1) . It is designed to indicate the current status of the ROV, including data from all the sensors, thrust of each motor, onboard tools status etc.

The angular position can be observed by the use of “compass” and “attitude indicator”. These two elements of the GUI are designed to look like instruments used in aviation because they can show the current ROV position in the most simple and clear analog manner.

A simplified drawing of the ROV is designed to indicate current thrust on each motor (Fig. 3.2). Color of the drawn thrusters tells us the amount of current through each motor (and therefore torque on the thruster propeller). Increase in current causes the color to change from green to red and vice versa. Exceeding of the current limit is indicated in red blinking of the drawn thrusters.

Areas located to the left and right from the drawn ROV are information panels. The right panel indicates data from the depth sensor and the measured distance. It also presents data from the position sensors in a digital form. Below there is a turbidity graph preview window. It allows us to observe data from the transmissometer for the last 10 seconds.

Fig. 3.1 Shore control station

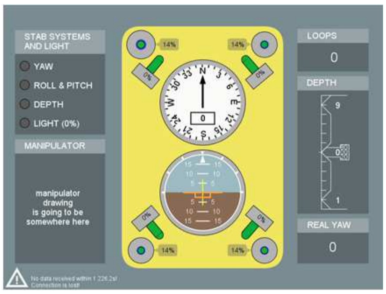


Fig. 3.2 GUI

Full graph window can be opened by a command from a joystick or a keyboard. In it we can change the graph scale and calculate an average value over time.
The left panel is designed to show the state of the ROV payload. At the top of the panel we can observe the brightness of light and the camera rotation angle. The current stabilization system mode is also presented there. Located below are simplified drawings of onboard tools that indicate their status (e.g. position of manipulator).

During the system operation some errors can occur, such as:

- loss of connection between the ROV and the control console;
- disconnection of a joystick;
- low GUI frame rate, etc.

The errors are indicated in the error handler window in the lower left corner of the screen. It contains a description of the occurred error and tips to eliminate it.

Akvator-3D design concept!
The background of the GUI is an image of a water column with bubbles floating in it. Watching these bubbles helps the pilot easily determine the direction, that the ROV is moving, and also helps to calm down and release stress.

3.2 Communication System

The Akvator-3D communication system consists of two subsystems, that intersect at the Communication Controller:

- Communication between the ROV and the Shore Control Station via RS-485 Interface;
- ROV microcontrollers inter-communication via I2C data bus.

“ROV-Shore” Channel

This kind of the connection should provide a satisfactory bandwidth on a quite long signal line (the current length of the ROV tether is 20 meters). We decided to use RS-485 interface that allows us to have a half-duplex connection with a speed up to 115200 baud per second. As the network topology is primitive (point-to-point), we decided not to use any of the existing "high-level" industrial standard network protocols and to write our own instead. With this simple asynchronous protocol we can elongate tether up to hundreds of meters without losing channel efficiency.

On the shore side, an x86 PC is used to communicate with the ROV. To be exact, it is an embedded PC board inside of the SCS.

The shore side software was created in Processing. This language and IDE allow us to work directly with PC ports and draw GUI. We have also used a Processing library to work with Saitek S-52 Pro controller.

The shore side software sends data to the ROV with a frequency of about 20-30 Hz. This frequency is only limited by the performance of the PC.

Onboard Communication Channel

For inter-controller communications we chose I2C interface, that is hardware supported by the AVR microcontrollers. This way we were able to make the electronics block in a form of a board stack. The communication controller as a Bus Master exchanges data with other controllers (Slaves). This exchange takes place inside of an Interrupt Service Routine, that is called on with a fixed frequency of 50 Hz.

3.3 Stabilization Systems

Our company control systems engineers developed heading, pitch, roll and depth stabilization systems for simplifying the ROV Pilot's tasks. The theory of its operation is presented in (Fig. 3.3). We chose the control system coefficients while modelling the ROV systems work in Matlab Simulink CAD. We use Propotional-Integral (PI) law in the Akvator-3D stabilization systems as a result of its capability to compensate the constant disturbance input. The ROV control system allows it to be fixed for one or more degrees of freedom simultaneously.

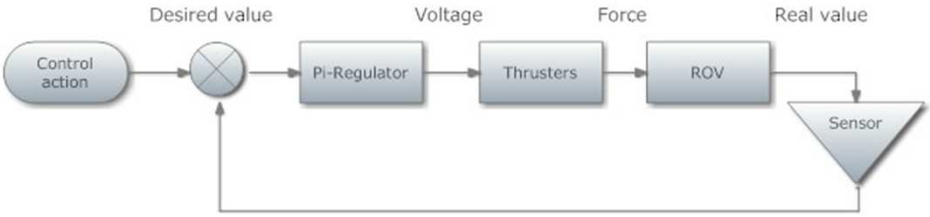


Fig. 3.3 Stabilization system flowchart

Our engineers created the algorithm of thrusters signals distributing for coordinating the stabilization systems signals together. The theory of its operation is based on cooperative processing of all stabilization systems signals. The flow chart of the Akvator-3D control system that clarifies its work is given below (Fig. 3.4).

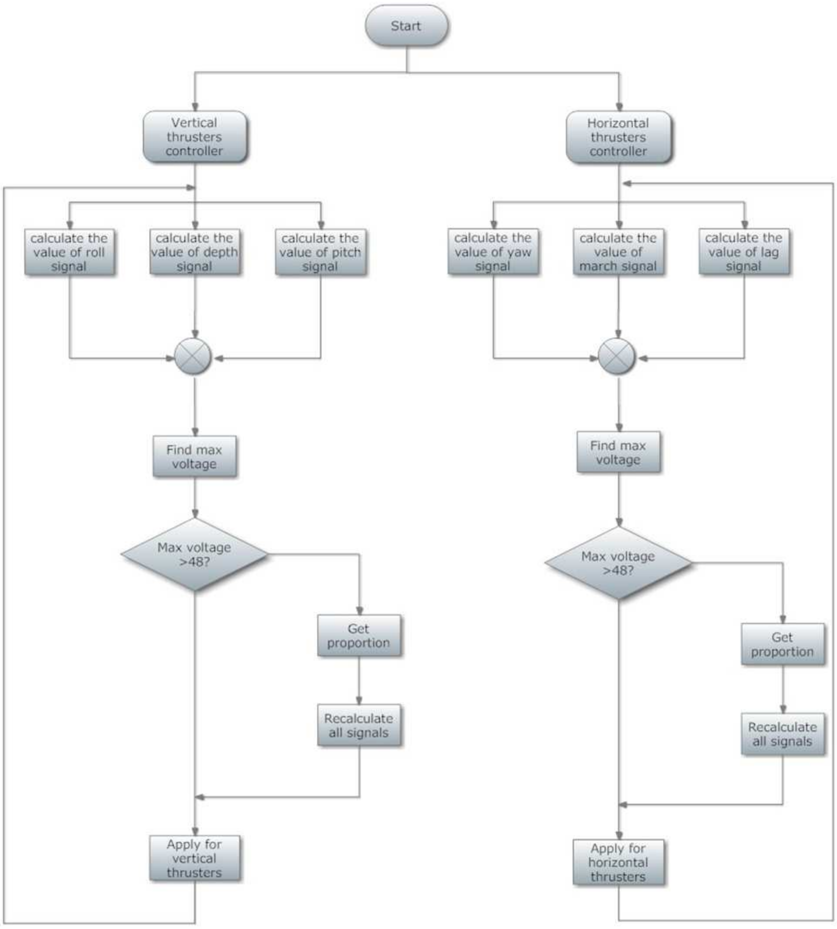


Fig. 3.4 Software flowchart

3.4 Length Measuring Video System

At one of the company conferences we decided to give up the idea of creating a special payload tool for the task of length measuring. It was decided to create a measuring system which uses the depth sensor data and video image from the ROV cameras for determining the length of the object. The system work algorithm is described below:

- The ROV plunges on the pool bottom and saves the depth sensor data.
- The ROV heaves up and directs its cameras on the pool bottom.
- The ROV fixes its position relative to the measuring object in such a way that the hole object should be in the sight of view of the ROV cameras and its borders should be placed on the image edges.
- Knowing the current depth value and the pool depth the special “shore” software calculates the ROV bottom standoff distance and the object lengths according to the formula (1):

$$L = 2\times(H_{max} - H_{ROV})\times tg(\alpha/2), \qquad (1)$$

where α is the ROV cameras observation angle (in water). We defined this angle via a special test stand.

This system allows us to achieve accurate object length without using additional payload tools.

4. Payload Tools

4.1 Manipulator

The Akvator-3D ROV is equipped with a 4-function electro hydraulic manipulator (Fig. 4.1). The manipulator length reaches 0.32 m. Being open in case of 10 bar pressure in hydraulic system the manipulator is capable of holding on 4 kg weight. It has wide operating area (Fig. 4.2) and is capable of working with objects that are located within the sight of the ROV cameras view or even situated under or over the ROV.

Safety comes first! ©

The manipulator safety features:

- The gripper “fingers” are covered with potting material layer. It increases reliability of the object fixing made by the gripper and its safety for living being;
- The current feedback allows us to control gripper pressure and the software developed by our company programmers turns off the gripper motor if it tries to press the object with strength dangerous for human beings;
- The hydraulic lines were designed in such a way that they can’t be damaged by any manipulator or other ROV payload parts.
- The system includes bleedoff valve that limits system pressure within 10 bars;
- All the hydraulic system components are rated for a minimum pressure of 20 bars;
- We designed a strange and curved shape of the manipulator frame for safety reasons but not only because of its aesthetics ones. The frame protects the hydraulic cylinders environmental influence in any manipulator position.
- The Biodegradable Food-Grade Hydraulic oil is used in our system.

The hydraulic system of the ROV is based on Leimbah Modellbau components that are usually used in a small type excavator, cargo truck and crane models that operate with heavy weights. As expected these components demonstrate excellent performance within our manipulator.

The ROV manipulator arm uses Seabotix gripper modernized by our company engineers. Its closing mechanism was replaced by our company's proprietary design which allowed us to shorten the gripper for 0.1 m and at the same time to save its operability.

Fig. 4.1 Akvator-3D Manipulator arm

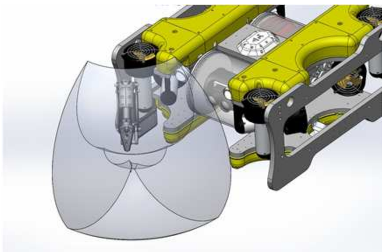


Fig. 4.2 Akvator-3D manipulator operating area

4.2 Leveling Tool

For performing the subtask of adjusting the legs of the secondary node our company engineers designed a special leveling tool (Fig. 4.3). The tool frame consists of polypropylene tubes. The leveling tool is equipped with a seal connector and a quick release mechanism for attaching to the ROV.

When the ROV accomplishes the subtask it puts the leveling tool onto the node legs and levels them via special effectors controlled by two servo motors.

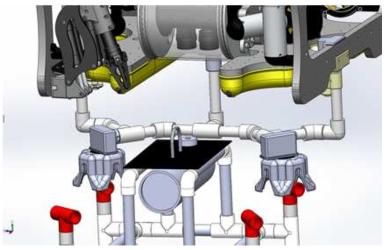


Fig. 4.3 Leveling tool

4.3 Transmissometer

The transmissometer construction consists of a frame, an electronics unit, light cap and light emitter unit. Its frame is made of PVC tubes and it fixes combined module of the electronics unit, the light cap and the emitter unit. The frame was designed in such a way that allows it to be centred relative to the seafloor platform rejected parts. The electronics and emitter units are sealed and produced on a 3D printer.

There are drainage outlets in the light cap for increasing transmissometer plunging rapidity.

The ROV manipulator clutches the transmissometer via U-shaped handle mounted on it.

The theory of transmissometer operation is based on measuring VD1 light beam attenuation via photoconductive resistor F1. The photoconductive resistor has a low resistance while the light is bright. The resistance of F1 increases as the light signal becomes weaker. The electrical schematic developed by our company's electronic engineers (Appendix 3) measures the difference between the supply voltage and the drop in voltage on F1.

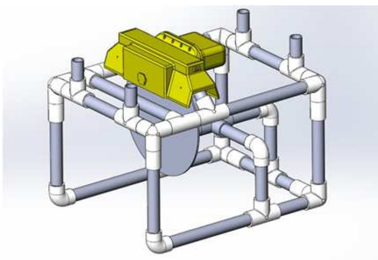


Fig. 4.4 Transmissometer

Last year our company developed a Shore Control Station (SCS). This year we've rebuild it.

SCS is a solid thick-walled case made of high viscosity polyamide plastics with positive buoyancy (Fig. 5.1).

SCS consists of next functional units:

- The aluminum frame with electronics units mounted on it (All SCS electronic components are mounted on the non-conducted stands);
- Joystick storage section;
- The face plate that contains a computer monitor and SCS control devices. The face plate is easily removable ;
- LCD Samsung UE40F6400AK 30-Inch widescreen display with support of 3D view technology. The monitor is mounted in the suitcase cover.
- The conectivity panel.

The SCS high strength construction provides protection of shore equipment during transportation. The SCS structure flexibility allows us to use it with both Akvator-2 and Akvator-3D ROVs.

The SCS helps to avoid trashed heap of wires, power source units and other equipment on the ROV Pilot workplace.

Fig. 5.1 Shore Control Station

6. Future improvements

This year our company have successfully designed a 4-fucntion electro hydraulic manipulator. Nowadays it doesn't have any position feedbacks. As a result of this fact we can't develop the end-point control system for simplifying Manipulator Pilot tasks.

Next year we are going to modernize the manipulator frame construction and to install encoders in its joints. One of our engineers has developed an end-point control system for our manipulator and modeled it in Matlab Simulink CAD.

7. Challenges

7.1 Technical Challenge

While constructing the buoyancy of the ROV we decided to choose polyvinylchloride foam PS-1-150 as a material for them. But we didn't foresee that this material is hard-to-treat. It was impossible to make aesthetic buoyancy for the ROV there were also a lot of cables connecting electronics pressure hull and thrusters and different payload tools. All these facts inspired us to create special covers for the ROV buoyancy (Fir. 1.2) Neat plastic covers hide and protect all ROV cables and balance weights. This solution increased the ROV safety!

7.2 Non-Technical Challenge

This year we've had a lot of aims and we've wanted to create a lot of complicated ROV systems. We decided to create a 4-functional electro-hydraulic manipulator, to develop the heading, pitch and roll stabilization systems, new electronics module, payload tools, etc.

That is why we asked ourselves: "How can we work against time? How can we streamline the work process?"

The JIRA project tracker, using Gantt charts and creating a mind map of the project were the answers. Creating the mind map of the project (Appendix 4) helped us to realize the amount of work we had to do. We understood that we had lack of programmers and design engineers. Gantt charts (Appendix 5) depicted time dependent behavior of the tasks, showed that we should give up some ideas that took too much time and helped us to control project deadlines. JIRA gave us an opportunity to track the project tasks achievements, to identify the problems that pull the project back and to exchange our ideas about different project problems.

Thanks to all this solutions our team created the ROV in a due time.

8. Lessons Learned

This year our company engineers have gained a lot of new skills. We described the majority of them in the other parts of technical report.

Technical skills gained by the company engineers:

- This year we've had successful experience of working with hydraulic systems;
- We learned how to create software in Processing language;
- We learned how to create heading, pitch and roll stabilization systems;
- We learned fundamentals of deviation theory and made magnetic compass calibration of VN-100 VectorNav sensor;
- We designed all PCB of the ROV in new for us Altium Designer CAD;

Nontechnical skills gained by the company engineers:

- We learned how to create the Mind Map of the projects;
- We found out how to use project tracking systems (such as JIRA);
- We learned how to organize laboratory workplaces;

9. Safety

This year our company has paid more attention to the problems or the ROV safety and put a lot of safety features in the ROV systems design. All these features are described in the corresponding technical report parts.

According to the safety politics of the company we developed Akvator-3D checklist (Appendix 6). This document consists of list of safety precautions for avoiding accidents while preparing the ROV for dive and list of pre-dive and post-dive compulsory check rules.

Besides the ROV safety problem we've faced the problem of the workspace safety in our laboratory.

Our company has a small lab (Fig. 10.1). At the beginning of the project our company discussed different ideas about the ROV and payload tools construction, our design engineers made blueprints of the ROV parts, electronics engineers developed electrical schematics and created PCB projects. But time passed. Different ROV parts became real.

Design engineers started to drill, to saw, to thresh different materials and parts, to do fitter's work. At the same time electronics engineers were soldering circuits and programmers were developing complicated software! Workspace in our laboratory was cluttered up with ROV parts, lots of cables and wires, etc. It wasn't easy to work in the laboratory and it was not SAFETY to be there! The work was paralyzed!

At one of the company meetings one of our senior members gave us an advice to create work zones and to use colored markings in our laboratory as it is in assembly halls.

We detected key features of all operations, changed tables arrangement and marked work zones.

All kinds of work with the ROV are carrying out at the large central desk which separates work zones for mechanical operations from work zones for programming and document management.

This decision increased the amount of workplaces in the lab and helped us to put the lab in order. We defined safe and dangerous zones in our lab. In the safety zone everyone can take off safety glasses, relax and have a cup of tea.

As a result of this solution we increased our company efficiency and decreased careless mistakes. We understood that teamwork is not only technical tasks solution but it is also well thought cooperating with each other.

**It goes without saying that all of the company engineers passed basic safety instructions test.*

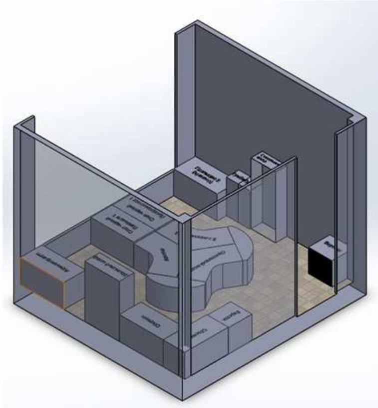


Fig. 9.1 Sketch of the new laboratory

10. Troubleshooting Techniques

This year our company have developed a special cameras rotary mechanism installed in the video system hull. This mechanism was based on using servo motor for rotating the camera platform. After the manufacturing of all pressure hull parts and providing all the assembly operations our engineers detected that while cameras were rotated the rotary mechanism had tremor at the end points of its rotation angle. We tested all electrical connections of the video system, measured servo motor control signals via oscilloscope but couldn't find the reason.

One of the design engineers suggested a hypothesis that servo motor gear system has axel plays or backlashes. One of our programmers suggested to add an aperiodic element in servo motor control system. As a result of this solution we've got the decreasing of the tremor. But we didn't want to make worse dynamic behavior of the control system that is why we added elastic linkage in the rotary mechanism and solved the problem.

11. Reflections

Participation in the 2013 MATE International ROV Competition is a great opportunity for all BMSTU team members: both experienced and new ones. We are grateful to MATEC for the chance to get experience in the development of a real underwater vehicle, and extend the boundaries of our competence. This is practical application of all knowledge that we receive during studies.

In addition we would like to add personal reflections of some BSTU team members:

Pavel Ikomasov: *"I like some parts of our project. Especially, I like to debug a stabilization system. To be splattered from head to foot – it always makes a lot of fun."*

Ekaterina Lyamina: *"While participating in this project I gained skills in electronics design, project management and control systems engineering. Working in the team of the ROV builders and participating in the MATE International ROV Competitions is the brightest time in my studentship"*

Natalya Petrova: *"While building the ROV we spent a lot of time together, overcame difficulties and became a solid team."*

Period: since 1.09.2013 till 20.06.2013
University: Bauman Moscow State Technical University
Mentor: Stanislav Severov
Funds: BMSTU; Tetis Pro Company; SM-11; Students

№	Item	Quantity	Price per item, $	Total amount, $
1	Thrusters, based on 150W MAXON (RE 40) motors*	8	1016,1	8128,5
2	Cameras pressure hull	1	794,3	794,3
3	Electronics pressure hull	1	856,0	856,0
4	Digital video cameras*	2	420,7	841,3
5	Rotatable camera box	1	769,7	769,7
6	Tether connectors**	30	42	840
7	Pressure sensor (strain sensor)	1	120,7	120,7
8	Orientation sensor VectorNav VN-100	1	717,7	717,7
9	Shore control system box	1	538,6	538,6
10	Manipulator frame	1	166,7	166,7
11	Hydraulic cylinders for manipulator	4	100	400
12	Hydraulic system pressure hull	1	1300	1300
13	Hydraulic system components (hydraulic pump, fittings, control valve box, etc)			1600
14	Camera and equipment servos	8	25,4	203,2
15	20W LEDs	4	28,4	113,6
16	Hardware platform Arduino	5	85,7	428,5
17	PCBs manufacturing	6	154,3	925
18	Secondary power supply unit	1	564,7	564,7
19	Buoyancy	2	128,3	256,7
20	Buoyancy covers	2	500	1000
21	The ROV part manufactured on a 3D-printer			1874,4
22	The ROV frame	1	204,3	204,3
23	Car monitor	1	416,7	416,7
24	200 Hz Display	1	789,7	789,7
	Total:			23 767,6

* re-used from the last year
**donated by SM-11 Department

13. References

1. Dr. Steven W. Moore, "Underwater Robotics: Science, Design & Fabrication", 2010, ISBN 9780984173709.
2. http://www.marinetech.org/
3. http://www.google.com

14. Acknowledgements

MARINE ADVANCED TECHNOLOGY EDUCATION CENTER

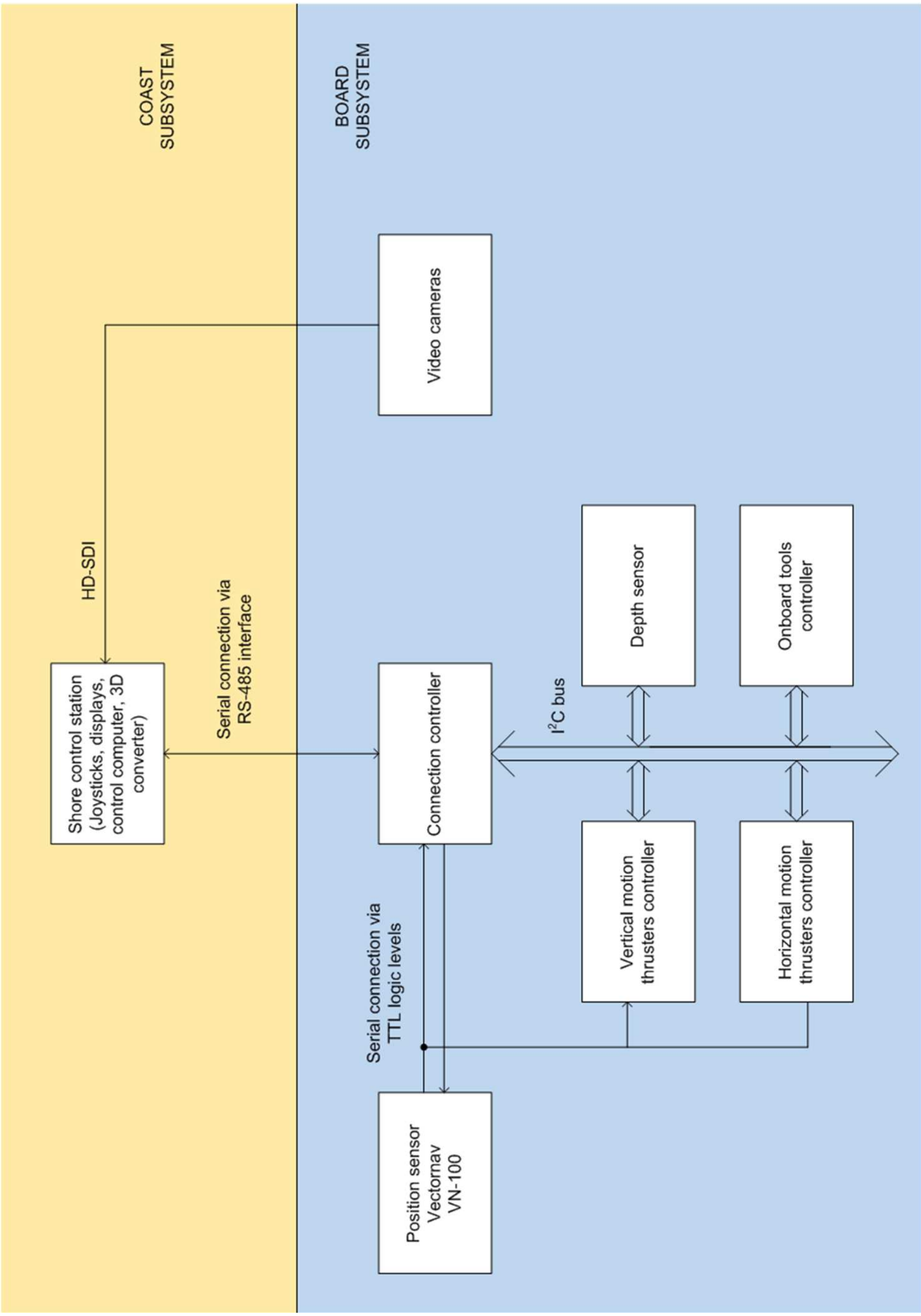
We have special acknowledgements to MATE Center for an opportunity to participate in these competitions. Due to your support we have the opportunity to actively study new world's problems and look for innovative ways of solving them. It allows us to expand our knowledge about the practical application of ROV in the different fields of science.

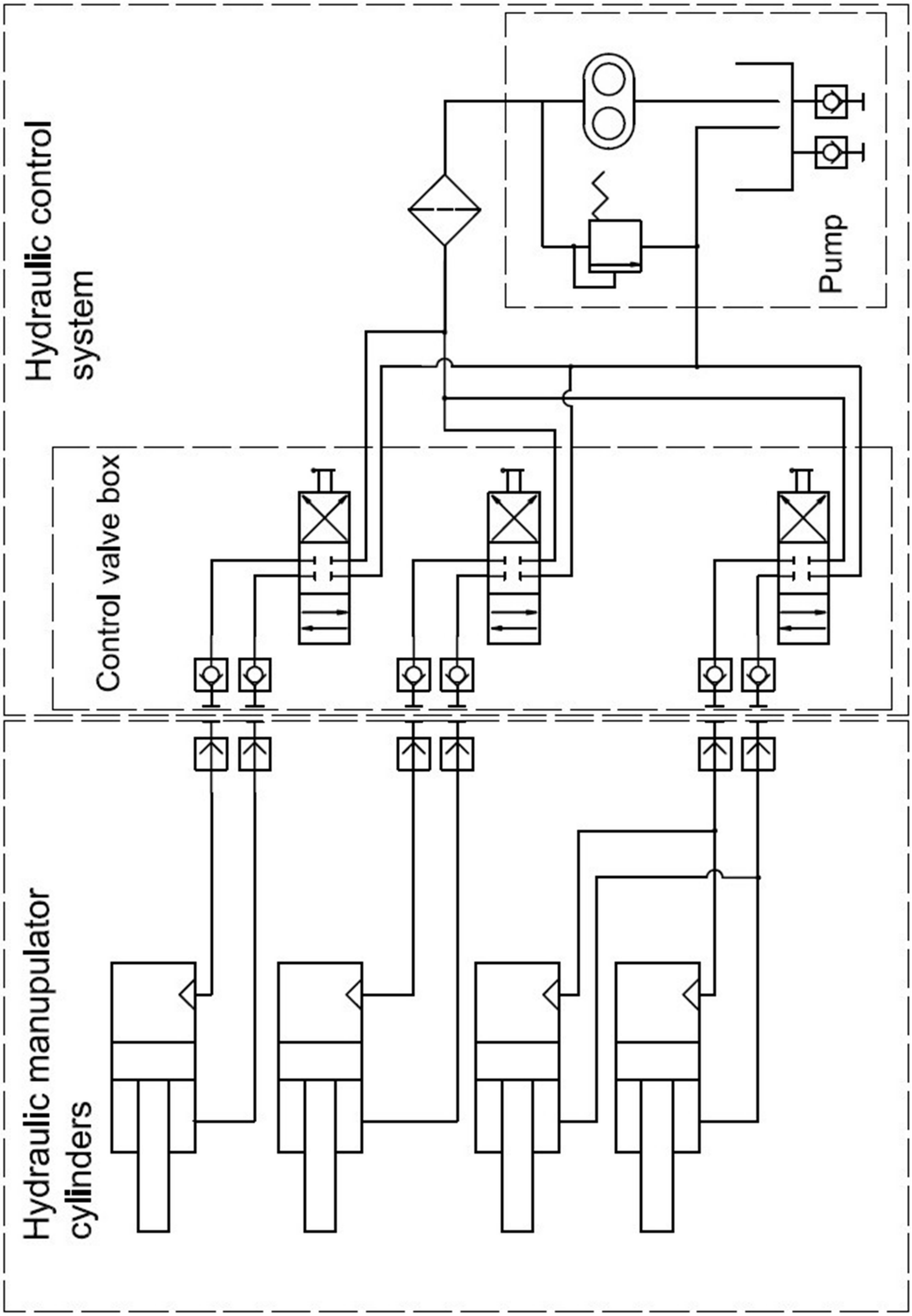
Special thanks for support and help:

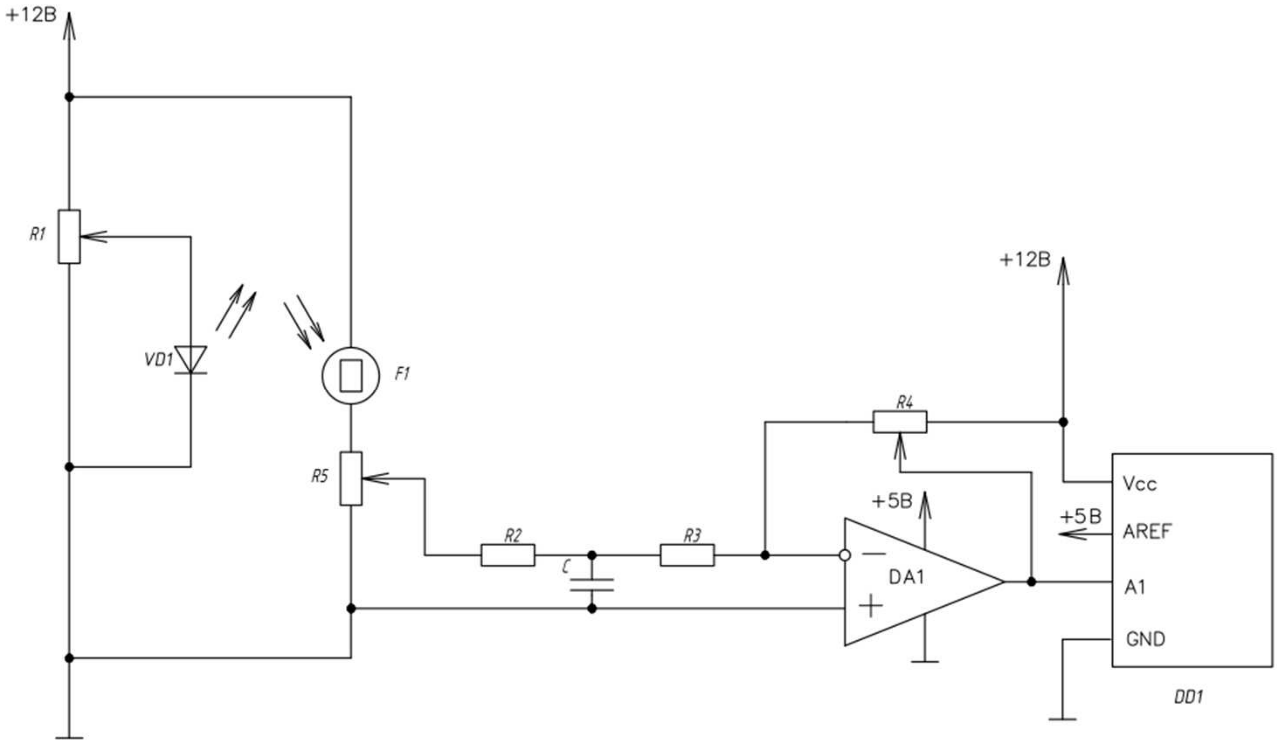
Bauman Moscow State Technical University

The SM11 Underwater Vehicles Department of Bauman Moscow State Technical University

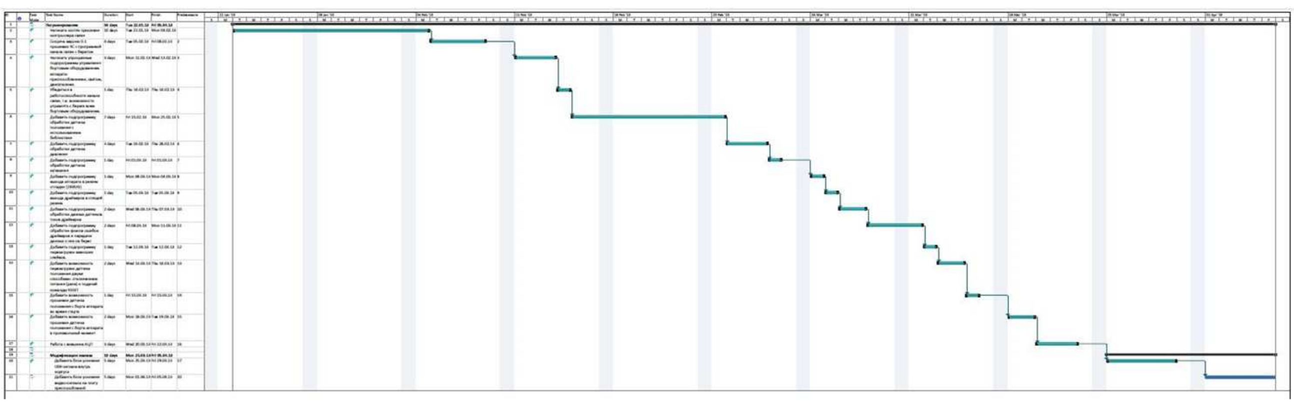
TETIS Pro Company

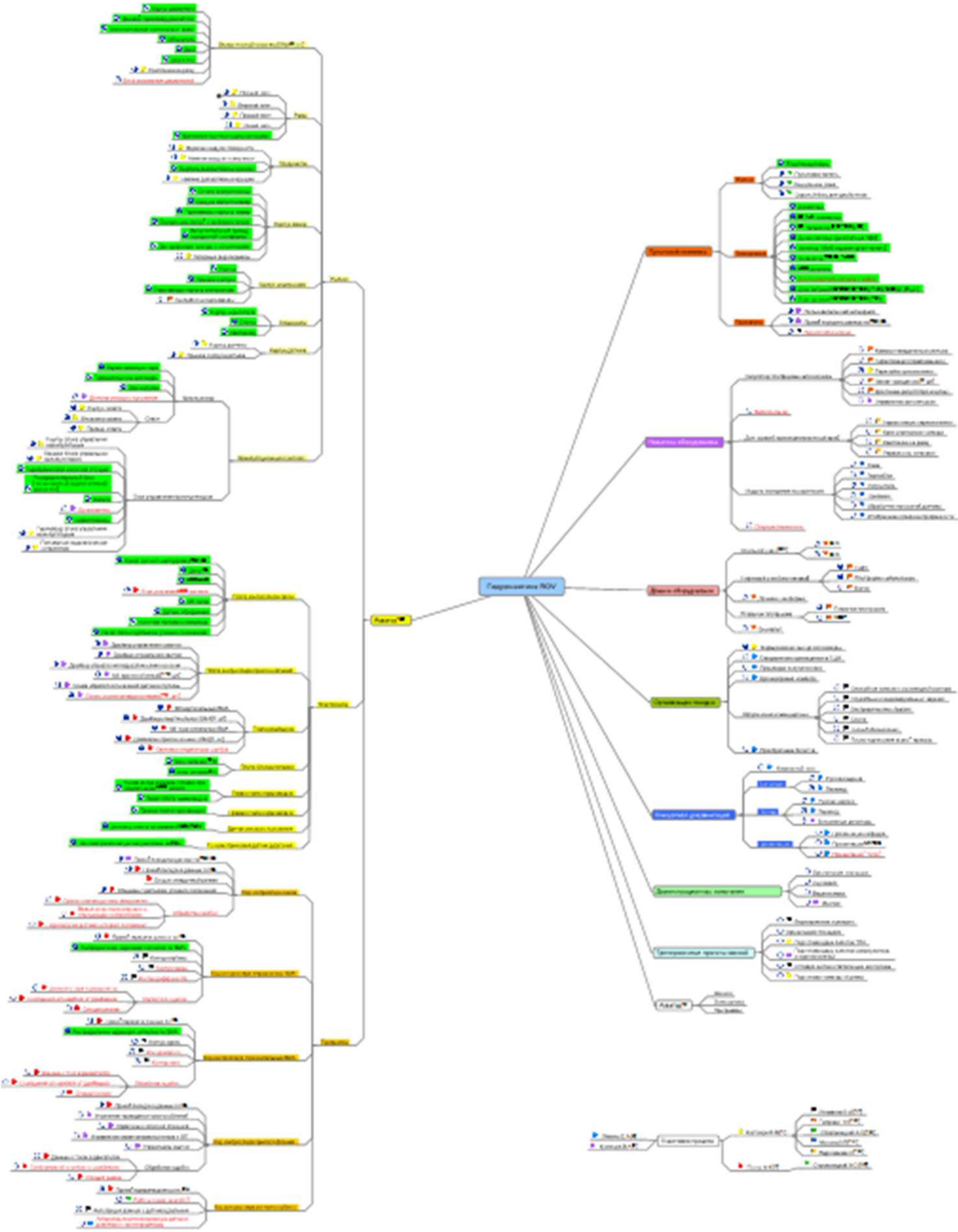

COAST SUBSYSTEM
BOARD SUBSYSTEM
Video cameras
HD-SDI
Shore control station (Joysticks, displays, control computer, 3D converter)
Serial connection via RS-485 interface
Connection controller
I²C bus
Depth sensor
Onboard tools controller
Vertical motion thrusters controller
Horizontal motion thrusters controller
Serial connection via TTL logic levels
Position sensor Vectornav VN-100


Hydraulic control system
Pump
Control valve box
Hydraulic manupulator cylinders



Appendix 4. Gantt Chart





Akvator-3D Safety Check List

NEW OPERATION

- Carry out a Site and Operations Risk Assessment
- Make access to, from and around the work site safe for yourself and any attendants
- Arrange for a suitable grounding receptacle with RCD protection
- Plan the Akvator-3D ROV deployment and tether handling arrangements best suited to the operation
- Plan and arrange the system and work area for safe and comfortable working

PRE-DIVE Checks

- Akvator-3D tested watertight
- Akvator-3D is ballasted and trimmed correctly
- Hook-up the Akvator-3D system and power up
- Check GUI screen registers all thrusters OK and no other warnings
- Check video picture clear, and monitor set for best viewing
- Check all warning lights in the electronics pressure hull
- Function of all Saitek controllers to check all thrusters turning, manipulators turning and light – maximum dry running 20 seconds
- Check that sensors and stabilizing system function properly

POST-DIVE Checks

- Akvator-3D tested watertight
- Check GUI screen registers all thrusters OK and no other warnings
- Check video picture clear, and monitor set for best viewing
- Check all warning lights in the main sealed housing
- Function of all Saitek controllers to check all thrusters turning, manipulators turning and light – maximum dry running 20 seconds
- Check that sensors function properly