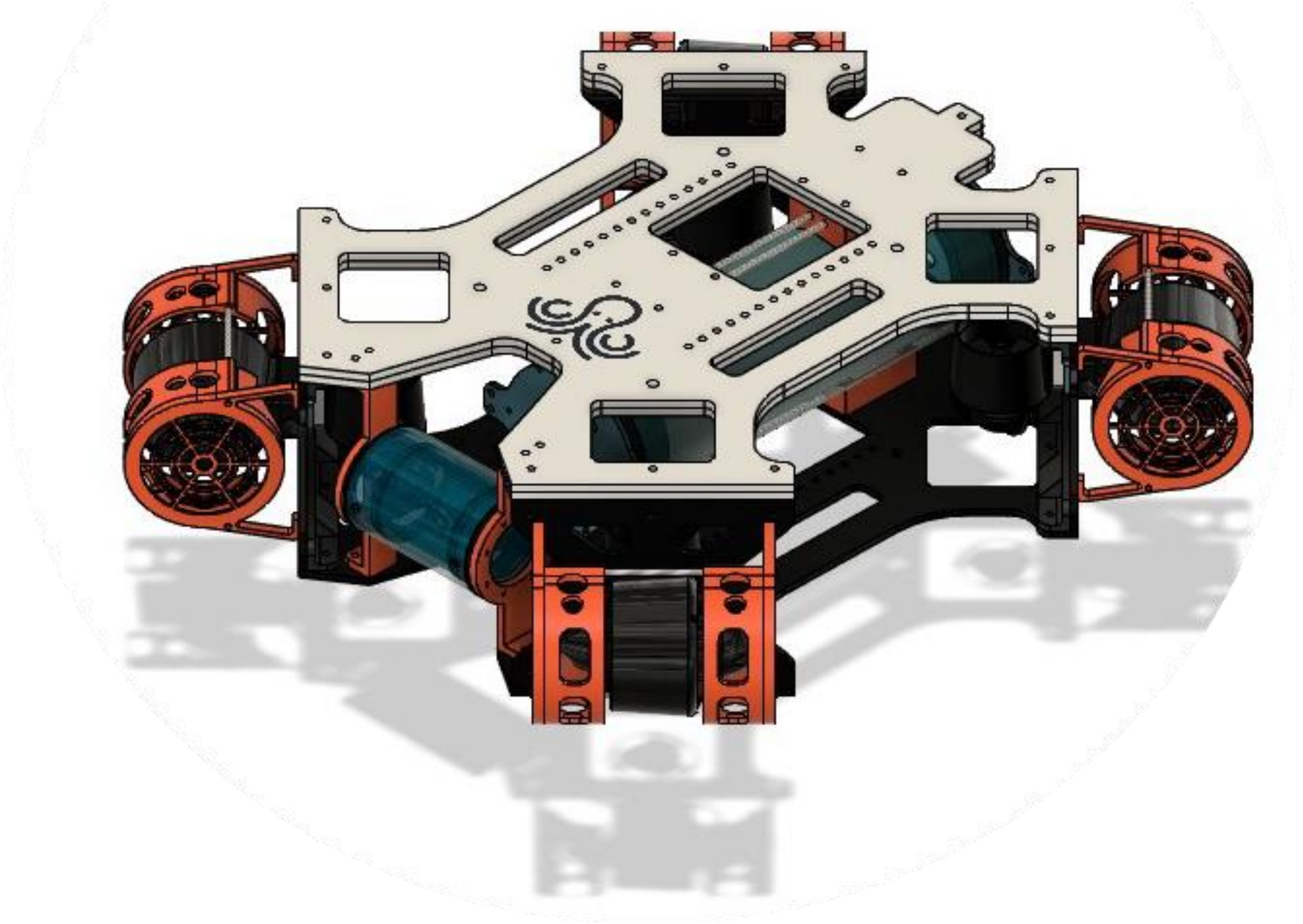

Technical documentation

KRAKEN’S TRAP

Students team of Siberian State Aerospace University named after M.F.Reshetnev

Krasnoyarsk city , Krasnoyarsk region

Gaiduk Alina – general manager

Buryak Danila – engineer

Kiyanenko Sergey – engineer

Kasimov Georgy – programmer

Manaeva Anastasiya – programmer

Petukhova Anastasiya - programmer

Ilina Sofia - electronics engineer

Introduction

Environmental pollution is an urgent problem in our time. Plastic, food and chemical wastes, petroleum products and much more have an impact on the atmosphere and on us.

Company "Kraken's Trap" has the necessary technical skill, the big experience of creating robots and necessary competencies for making Remotely Operated Vehicle (ROV), capable of purifying the planet's aquatic environment.

ROV Whydah is the result of months of work, planning and explores. After lots of tests in many difficult conditions, vehicle demonstrated good maneuverability, high speed and efficiency in performing assigned tasks.

Uniqueness of the robot achieves by lightweight construction, reliable electronics and innovative software.

This technical documentation describes process of developing and assembling, these makes ROV Whydah the best for performing the following works:

1. Remove floating plastic debris from the water surface
2. Change mesh catch bag into the Seabin
3. Determine the health of the coral colony
4. Propagating corals onto a reef
5. Make an injection of a poisonous starfish
6. Collecting a sample of the sponge
7. Change the trap for eels
8. Create a photomosaic of the subway car

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About company

Company description

Kraken's Trap company consists of students of the Krasnoyarsk University - Siberian State University and students of secondary School 143. For employees, this is the first experience of participating in the MATE ROV competition in the Explorer class. Despite this, the participants have extensive experience in preparing for various competitions. This experience was very helpful for everyone. It is not only provided a great store of knowledge in the field of robotics, but also helped to avoid some mistakes that were made in the past.

Creating a robot for us is not just about designing, assembling, and programming, but something more. Each of our employees makes a huge contribution to our common cause. The company worked on all the components of the ROV: its mechanical part, electronics and software.

Picture 1.Team photo

The structure of the company

General manager of the company

Gaiduk Alina - 1st year student of the Siberian State Aerospace University named after M.F. Reshetnev

Electronics engineer

Ilina Sofia - student of the 11th grade secondary school №143

Engineers

Buryak Danila - 1st year student of the Siberian State Aerospace University named after M.F. Reshetnev

Kiyanenko Sergey - 2nd year student of the Siberian State Aerospace University named

Programmers

Kasimov Georgy - 1st year student of the Siberian State Aerospace University named after M.F. Reshetnev

Manaeva Anastasia- student of the 10th grade secondary school №143

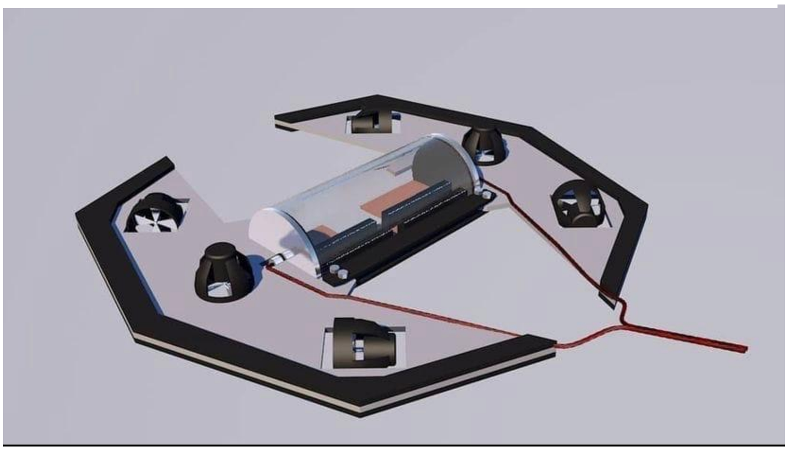
Project justification

Evolution of design and construction

The company took a responsible approach to the creation of Whydah. In order to find the best construction variant, during a brainstorm, were created several concepts of the apparatus.

Initially, Kraken's Trap wanted to create a small in height, almost flat robot. It contained six motors. During the discussion, the employees realized that this variant was absolutely irrational:

Picture 2. The first robot prototype

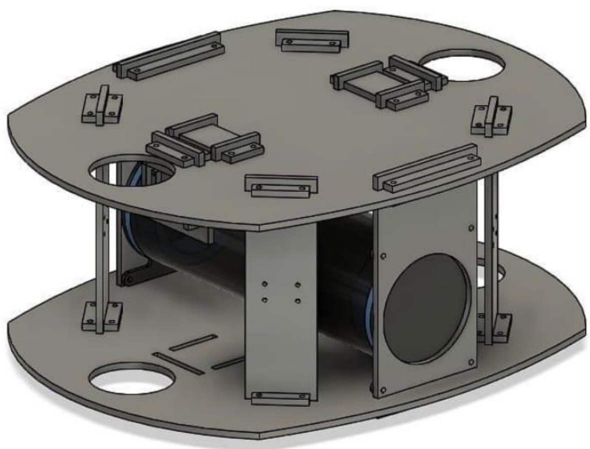


1. First, four small motors for driving will not provide a high enough speed.
2. Secondly, such a robot frame did not allow the installation of a manipulator and other payload.
3. It is also very difficult to achieve the stability of this structure in water.

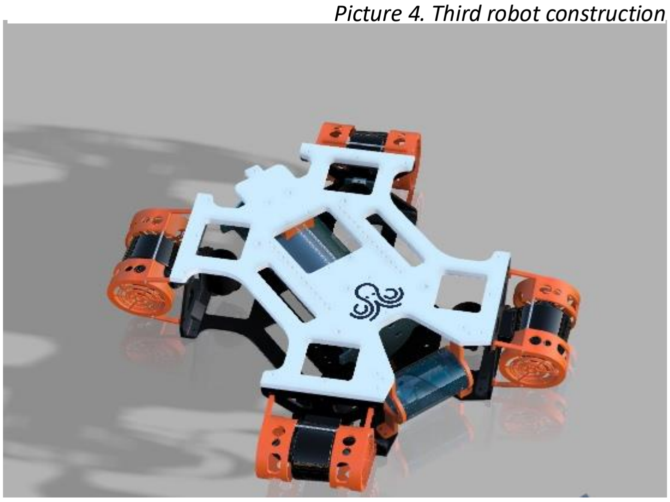
This construction was only in sketches. Company did not create this robot.

The second version of the robot was pilot. The company's employees decided to create a trial construction of the robot to identify the flaws and create the best version of the apparatus. The problematic of this construction was in the difficult access to parts and assembly. Moreover, access to electronics in a sealed flask was limited. This option was also irrational, because the Kraken's Trap company for the correct timing. The body of the second version of the robot was assembled, so the company's employees decided to use it to wind the cable.

Picture 3. Second robot construction



Picture 4. Third robot construction



As a result, the employees created our ideal design, which has all the necessary characteristics. Until now, something has changed and improved, but the basic construction remains the same.

Production process

The first stage is the generation of ideas and their discussion, as well as the study of information.

The production of the robot began with a brainstorm. The employees discussed the tasks of the competition and the tools available to them. It was decided to assemble a ROV capable of performing all the necessary tasks in the right time, and with the ability to change the payload. The size and weight of the structure, cost, labor intensity of work, availability of technologies and safety were important for the company.

A list of necessary parts and components were compiled. The employees discussed what parts can be made on their own, the availability of some components, as well as their quality. Based on this, it was decided what to buy, and orders for these components were made.

The second stage is creating a 3D model of a robot, printing parts, preparing them for assembly, thinking over a circuit, studying information for a future program and initial assembly.

After developing a 3D model, the company started creating a robot. The engineer printed the plastic parts on a 3D printer with 100% filling, followed by post-processing of the acetone bath, so that the parts were not filled with water and the ballasting did not change. The acetone bath allows the layers of plastic to melt and stick together. Thus, it is possible to get rid of the porosity of the structure of the parts.

The robot frame was manufactured using a CNC milling machine. After this procedure, it was necessary to manually process the parts: remove chamfers, give the holes a nominal diameter.

During the production of the ROV, the company's electronics engineer was engaged in the design of the electrical circuit: the location of all the electronics elements of the underwater part of the electronics. After that, she connected the motors, sensors, and cameras to the board, running power and communication wires for each element.

Programmers at this time were writing code. First, programs were written for client-server communication between the control system and the robot, and then the code for the joystick was changed, taken from GitHub with a free license.

The company's engineers also sealed all the penetrators with epoxy resin. This is a very complicated process, it is necessary to calculate the right amount of resin, and also give it time to harden.

The third stage is assembling, writing a program, error correction, testing.

During the third stage was made a final assembling of the robot. Motor protection attached, a flask with electronics assembled and checked its tightness.

Programmers Georgy and Anastasia were writing code for Open CV. Then the construction, electronics and software were tested. Was checked the work of all motors, manipulator and camera, during this testing the programmers debugged the code.

The fourth stage is testing and troubleshooting.

Kraken's Trap has signed an agreement with the Water Sports Palace of the Siberian State University for testing robot.

First testing:

1. tightness che cked;
2. ballasting completed.

Second testing:

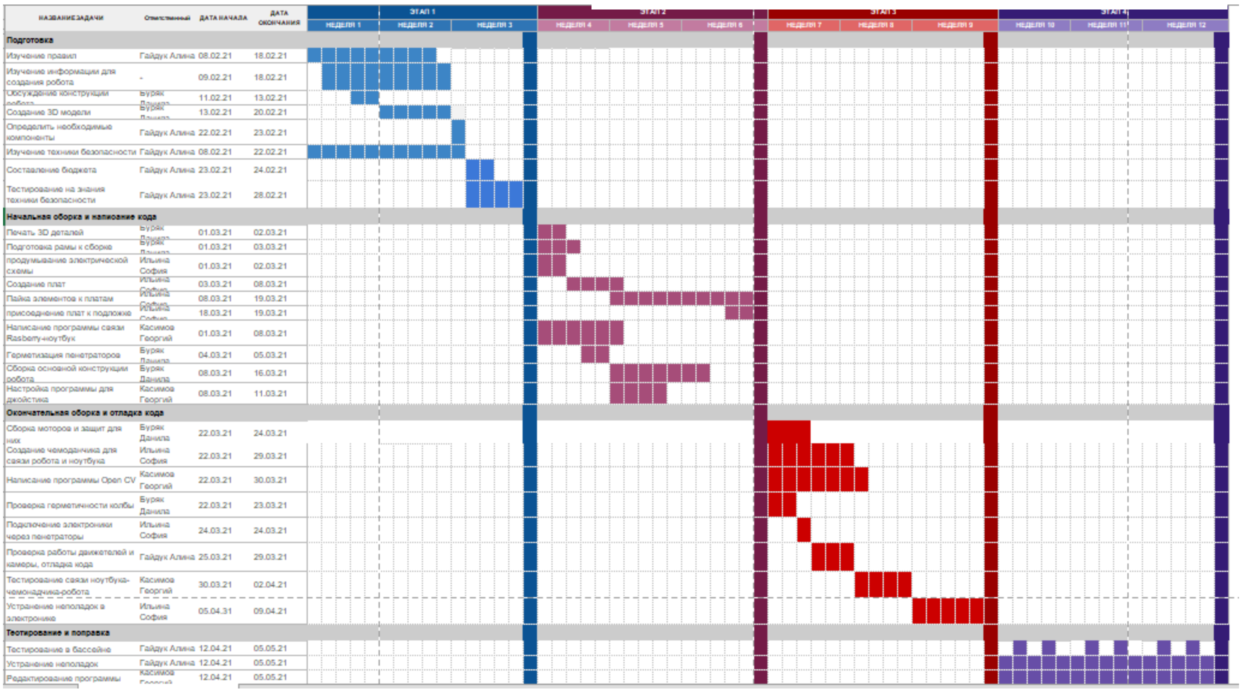
1. tested the operation of cameras and motors;
2. swim made.

In the following trainings, the company conducted tests on MATE game models.

During the fourth stage, troubleshooting and revision of the software code were carried out. The design has changed slightly. It was decided to create lower supports for the robot to avoid damage to the manipulator.

Each stage was very important, the process of creating a robot is a laborious task that requires a lot of time and effort. To monitor the implementation of subtasks, a schedule was created and placed in the cloud service, and each participant could view the current tasks assigned to him and mark the progress of their implementation.

Picture 5. Schedule

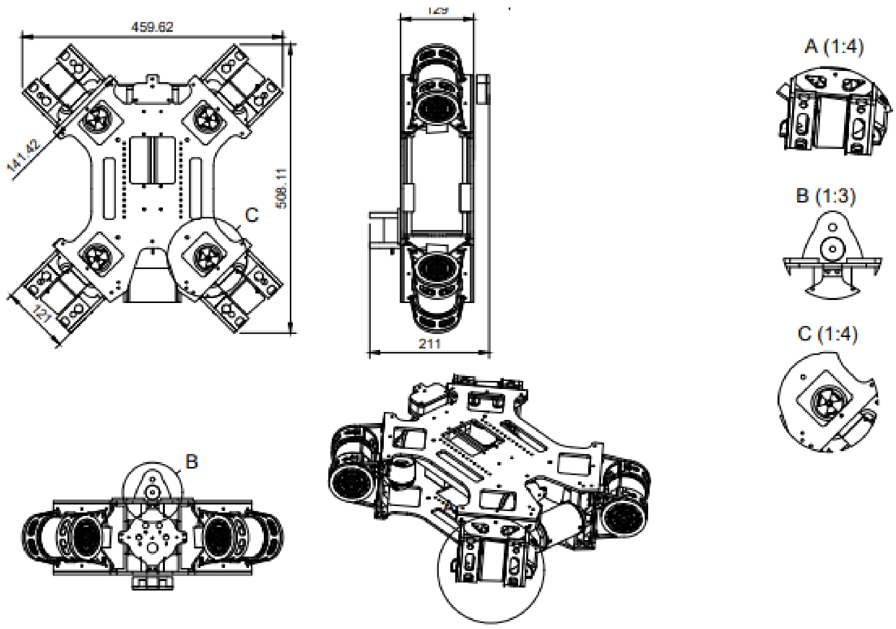


Available tools

For mass production of the ROV Whydah, were selected the available production methods and mechanisms. CNC milling machine and 3D printer have high quality production and precision in the manufacture of parts. Using this technical equipment, the company increases the productivity of its employees. Each instance of the ROV is developed with calculations of hydrodynamic drag and buoyancy force, which makes it easier to ballast the underwater vehicle. For these calculations, the company uses various programs, which allows to maintain the accuracy of these calculations.

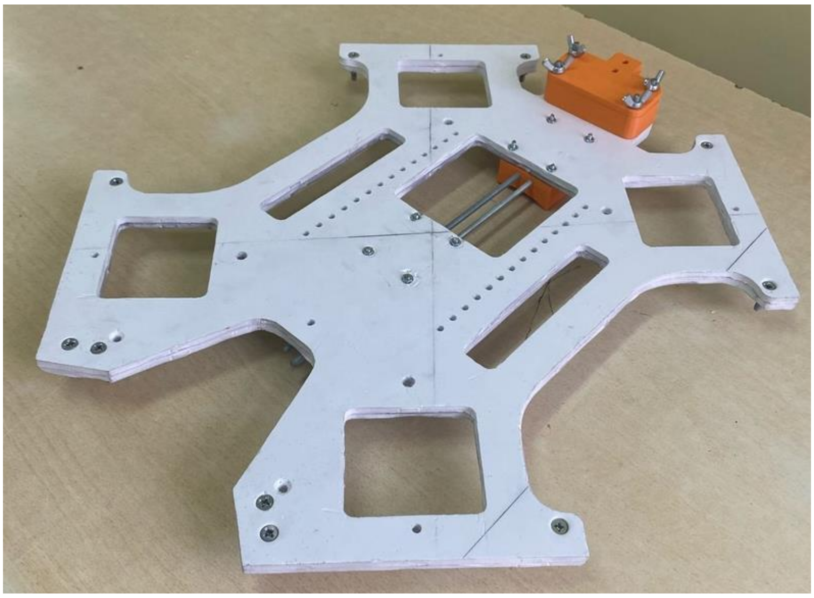
Mechanical components of the robot

Picture 6. Assembling ROV



Picture 7. Robot drawing

Frame


Picture 8. Robot frame

The lower frame of the robot is made of a composite material, which consists plastic and aluminum. The upper part of the frame is made of positive buoyancy material, made of foamed polyvinyl chloride. It is lightweight and compact enough to pass the competition rules, as well as simplifies the transportation, launching and raising the ROV to shore The design has an unusual X-shaped shape, and the size is 460x336 mm, it reaches a height of 200 mm (without a trap and manipulator), if you install them - the height will be 250 mm.

The construction of the frame has minimal hydrodynamic resistance due to special cutouts through which water flows freely through the ROV.

There are holes on the upper and lower planes for installing the payload.

Color spectrum of the robot is made in white, black and orange. This will help to see the robot well underwater and keep personnel safe. The visibility of the robot model in these colors has been verified in Fusion 360.

Motors

We use the MUR Thruster 1500 and MUR Thruster 200 brushless motors, because compared to the collector motors, they are able to operate under water, as well as they are easier to connect and operate, have greater energy efficiency and high torque. During the brainstorm, we determined that we need lag motion, as well as change our roll and trim by installing 4 motors at an angle of 45 degrees relative to the longitudinal axis of the robot.


Pictures 10,5. Motor MUR Thruster 200

Due to the limited budget, the company was unable to buy a full set of high-power motors. However, there was a smaller form factor and power motors in stock. After analyzing the tasks of MATE, we came to a compromise, setting large motors for movement, and four small motors for diving. Because of this, the robot can move quickly, and when performing work, it uses small motors to slightly change or maintain depth, and if it is necessary, the main ascent or dive uses large motors using roll.

The motors are equipped with protection, which the company came up with during one of the meetings. This not only avoids injuries to the limbs, but is also necessary to complete some tasks.

Manipulator

Picture 11. Manipulator

Kraken’s Trap company create unique manipulator construction and gripping technology. Manipulator has a moving part, its needed to capture. Moreover, at the right time you can put on and disconnect the manipulator. It is driven by an underwater sealed servo. The design itself was 3D printed.

Supports

To avoid damage to the manipulator, supports were created. The fact is that the manipulator is at the bottom of the robot, so it pressed on the structure with all its weight. Supports help to avoid this. In addition, it lowered the point of attachment of the ballast relative to the center of buoyancy, which had a positive effect on the stability of the robot.

Picture 126. Support

Camera

The robot uses the MUR camera, which is located in a sealed vessel. It is installed on a servo. Therefore the camera can change its angle of inclination, which makes it easier to perform many tasks in competitions. The rotation angle of this camera is 180 degrees, the resolution is 976x494.

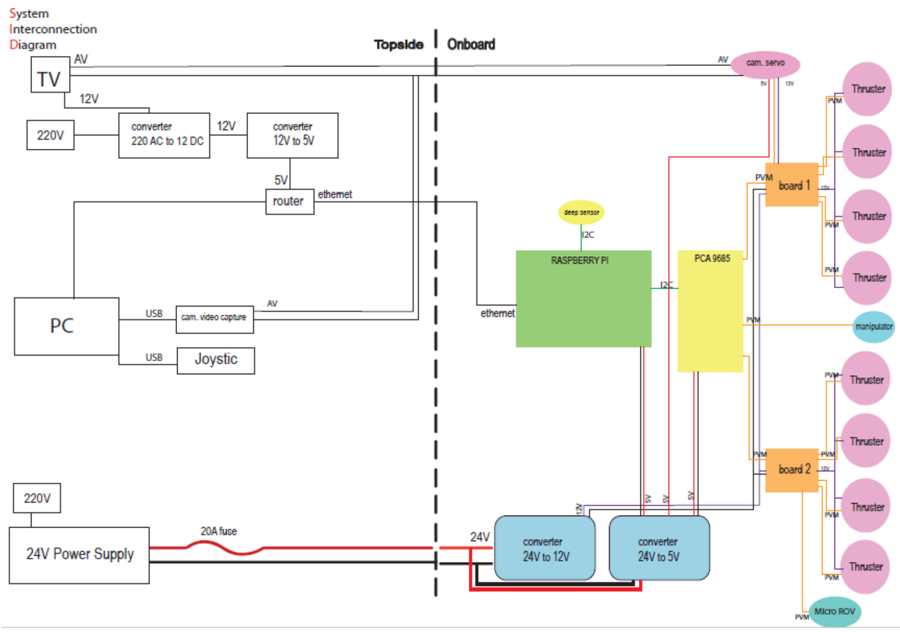
Picture 13. Camera

Electronics

The flask is made of plexiglass. Aluminum flanges are installed on the sides, on which there are rubber seals. The part of the flange with holes for penetrators was developed and manufactured on a CNC milling machine by employees of the company.

Electrical diagram

Picture 12. SID diagram



The underwater part consists of two DC / DC buck converters, a Raspberry Pi 4 single board computer, a PCA9685 PWM controller and two power distribution boards of our own production.

A current of 48V is supplied to the board, which then enters two converters: the first one gives 12V at the output. Next, the 12V current goes to two mini-boards (motors and a servo drive from the camera are connected to them), as well as to the second converter. The second converter receives 12V and outputs 5V. The 5V current then goes to the servo and the Rasberry Pi.

Overwater part:

In the overwater part, we use 12V and 48V power supplies. 12V supply powers the TV and the 5V converter, which supplies power to the router. 48V is needed to power the ROV, the control system uses a computer, a joystick and a video capture board, in order to convert an analog image into a digital one and display the image on the computer, which is necessary for performing offline tasks.

Software

All of the robot's software was written in Python. It was chosen by the company's programmers because of its versatility and convenience, and also due to the presence of many required libraries. The robot is controlled by a Raspberry Pi microcomputer, laptop и PCA9685 module, which uses I2C interface. This module can control 16 motors or servos, which fully covers the company's needs. The code for this module was taken from the open source GitHub.

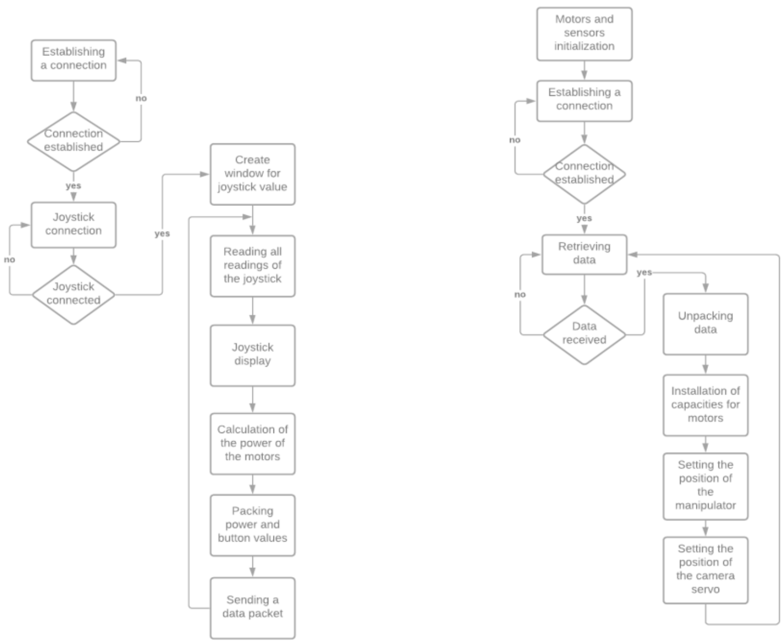
In addition, the robot is equipped with a depth sensor, which also works by using I2C interface. The data from this sensor allows you to hold the depth for some tasks.

The basic code for control is located on the laptop, to which the joystick is connected. The laptop and the power and signal station are connected via an Ethernet cable.

The program is implemented as a set of functions that perform various actions. Some functions read values from the joystick using the library for this model, taken from GitHub. Other functions calculate powers for the and values for the servos, using the values obtained, and then pack them into a byte data packet that is sent to the Raspberry. This data is sent using Socket Server.

Moreover, our company uses the functions of the Open CV library required for image processing and object recognition.

The code, which is on the Raspberry, accepts the sending of the value, unpacks the data packet and sets the required powers for the thrusters and values for the servos.



Picture 13. Software block diagram

Archimedes' law for calculating buoyancy

The ROV Whydah has a neutral buoyancy. This helps to minimize any load on motors during missions and make it more stable. For this, the robot's weight must be equal to the force of Archimedes, according to the principle of Archimedes.

Floating material or rigid polyurethane foam with a density of 36 kg / m^3 is used to increase the force of Archimedes. We calculated the required volume of foam and ballast, and achieved that the robot floats in the water column.

Problems and difficulties during the work

During the work , the company Kraken's Trap faced several difficulties:

1. We have lost a lot of time due to the Covid-19 pandemic. Our laboratory was closed due to restrictions imposed by the governor's decree, so there was no place for employees to work. Because of this, we had to postpone the creation of the robot indefinitely. The discussion of the construction was not stopped, a meeting was held on the Discord online platform. At this time, engineer Danila was creating a 3D model of

the robot at home and was able to print some details on a 3D printer. After the restrictions, a new work schedule was created, and the company began to work hard on creating its product.

2. The second problem faced by Kraken's Trap employees is the difficulty in creating a work schedule Most of the employees are students of the Siberian State University. Different class schedules made it difficult for everyone to get together at the same time. It was decided to hold meetings in this way: a general meeting is held once or twice a week to solve the company's problems, discuss and help each other. To follow the work schedule, electronics, programmers and engineers met at different times, convenient for everyone. Thus, the company managed to create a robot by the deadline.

3. The third problem occurred two days before the scheduled testing. One of the dive motors burned out due to polarity reversal and incorrectly connected. Of course, this slowed us down a bit, because instead of working with the code, namely testing the work with the motors, manipulator and camera, it was necessary to connect two new motors, because they are connected in pairs. As we had two spare motors, the company employees immediately got to work. Sonya (the company's electronics engineer) began to lengthen the wires on the new motors, Danil (the company's engineer) replaced the old ones with new ones. In this way, this error led to a loss of time, but it taught employees to be attentive and quickly make troubleshooting decisions.

4. In the original version of robot, it was decided to create a manipulator with two degrees of freedom: for turning around its axis and grasping. Due to lack of time, the company did not have time to implement the idea of turning around its axis.Безопасность

Safety philosophy

Kraken's Trap cares about the safety of not only its employees, but also those around them. Everyone has the right to a safe work environment. By following safety procedures, the risk of occupational injury is minimized. That's why we've developed a safety protocol that all our employees study carefully and follow. Each Kraken's Trap employee is rigorously trained and tested.

There are four blocks in the safety protocol: operation in the lab, transport, operation before startup and during startup. They list all the rules that will help you avoid injury.

Employee training

Each employee receives safety training at the beginning of each season. Despite this, experienced employees of the company help newcomers throughout the entire work process. They teach the correct use of tools, as well as monitor the observance of safety rules. Moreover, employees who are not experienced in CNC milling machine and 3D printer are not allowed to work with these machines. For admission, they need to undergo training, and then a probationary period (launching machines under the strict supervision of experienced participants).

In this way, it not only helps to avoid injury, but also brings company employees closer together.

Safety features of the ROV

Whydah ROV meets all safety requirements. Sealing rings and epoxy filling, where waterproofing techniques are used to ensure that all electronics stay dry, protecting staff and equipment from the risk of electric shock. This ensures the safety of personnel and the work area.

Each ROV motor is equipped with a protective grid for limb safety.

Work area safety

The safety of the work process is achieved not only through careful control of safety knowledge, but also through an equipped laboratory. A range hood, personal protective equipment, fire extinguishers and an electrical control unit make the workspace safe for employees. The laboratory is divided into several working areas: soldering, programming, for working with power tools, assembly and a separate place for working with a CNC machine. This separation helps keep employees safe and also helps them focus on their work, which is definitely important.

Safety protocols

Safety protocols (Appendix 1) are followed during all work with the robot. This is necessary for the safety of the entire team of employees, as well as in order to avoid damage to the robot.

Special safety protocols are used to ensure a safe working environment while working in the laboratory. Kraken's Trap uses Occupational Safety Analysis (JSA) forms to be created and verified by employees before performing risky operations. The safety protocol is updated every time a new manufacturing process is introduced. Employees are required to comply with these requirements when starting, working with the robot, and also to maintain safety on the water.

Material support

Budget

At the beginning of this season, Kraken's Trap allocated a budget and calculated the approximate costs of preparing for the competition, as well as travel expenses. Based on discussions about the availability of components and the ability to produce them independently, a need was identified for the purchase of components indicated in *Table 1*. For the trip to the venue of the competition, the company allocated funds for the purchase of tickets, payment for accommodation and an organizational fee. The total cost of the TNPA with the available components is shown in *Table* 2. The costs of travel to the competition in Vladivostok are shown in *Table* 3.

Table 1. Travel expenses

Name	Price per person, USD.	Number of days	Number of people	Amount , USD.
Flight Krasnoyarsk-Vladivostok-Krasnoyarsk	289	-	6	1734
Accommodation	27.5 (per day)	4	6	660
Arrangement fee	220	-	(Arrangement fee applies to all team members)	220
			Total	**2614**

Table 2. Robot parts cost

Name	Price for one, USD.	Number	Amount, USD.
Underwater motor MUR Thruster 1500	206	4	824
Depth sensor MUR Depth sensor	27.5	1	27.5
Sealed case	55	1	55
Hermetic connector 4pin	82.5	1	82.5
Hermetic connector 8pin	41.25	1	41.25
Penetrator	8.25	5	41.25
Underwater rotary camera MUR Rotate Camera	137.5	1	137.5
Flange 90	30.25	2	60.5
Joystick	151	1	151
		Total	**1420.5**

Table 3. Full cost of ROV

Name	Price for one, USD.	Number	Amount, USD.
Underwater motor MUR Thruster 1500	206	4	824
Depth sensor MUR Depth sensor	27.5	1	27.50
Sealed case	55	1	55
Hermetic connector 4pin	82.5	1	82.5
Hermetic connector 8pin	41.25	1	41.25
Penetrator	8.25	5	41.25
Underwater rotary camera MUR Rotate Camera	137.5	1	137.5
Flange 90	30.25	2	60.5
Joystick	151	1	151
Keyboard	6.88	1	6.88
Screen	20.6	1	20.6
Power supplies	41.25	3	123.75
Indication of current and voltage	6.88	1	6.88
Converter	6.88	2	13.75
PWM controller	4.13	1	4.13
Dive motors	27.50	4	27.50
Servo	6.88	1	6.88
Board Rasberry Pi 4	55	1	55
		Total	**1685.87**

Manufacted vs Purchased vs Recycled

Kraken's Trap company rationally distributes its budget, so we make most of the parts ourselves or reuse existing components. We bought only those parts that we could not manufacture ourselves or that had become unusable. The main criteria when choosing to buy or create were:

1. The possibility of manufacturing this component independently (availability of technologies)
2. Time costs
3. The cost of a new part

Since our laboratory has a 3D printer and a CNC milling machine, it was not difficult for us to make the basic design of the robot ourselves. Therefore, we made all the mountings, frame, motor protection and parts of the manipulator ourselves.

Since our employees had previously participated in other underwater robotics projects and competitions, we had a lot of needed parts that we could use again. But we were not able to reuse all the details. For example, we had small motors (MUR THRUSTER 200), they had a small thrust, so it was decided to purchase new motors with better characteristics. The main criteria for reuse were:

1. Characteristics of the available parts
2. Cost of new parts
3. Rationality of their repair

Table 4 is a list of what the company has made, bought and reused.

Table 4. Parts list

Manufactured	Reusable	Purchased
• Robot frame • Motor protection • Camera mounts • Flask mounts • Parts of the manipulator	• Keyboard • Screen • Power supplies • Indication of current and voltage Converters • PWM controller • Dive motors • Servo manipulator • Raspberry Pi4 board	• Camera • Flask • Flanges • Penetrators • Connectors • Motors for movement • Joystick • Router • Wires for cable rope

Conclusion

Team challenges

During the work, the company's employees had to solve problems with communication with the robot, as well as with electronic components. During testing, it was difficult to connect to the robot, this was due to bad wires, a weak laptop, so we had to constantly reboot the robot. Also, problems with electronics took a lot of time, the wires often came off, and they did not lie neatly in the flask. After the cable management was carried out, this problem was solved. The company managed to solve the communication problem by buying a shielded wire, as well as by using another, more powerful laptop

Future improvements

Kraken's Trap company is not going to stop there. Each employee should improve their skills, which will help make the device better, as well as avoid mistakes. Also, future changes include improving the manipulator, adding a second rotary mechanism to the design, as well as a method for quickly replacing it.

To improve the work of employees, the company plans to revise the work schedule for a more uniform load on different departments.

Thanks

For assistance in the creation of the underwater vehicle, the company would like to thank:

1. MATE Center for the opportunity to participate in competitions

2. Robocenter and Sergey Alekseevich Moon for organizing all-Russian competitions in the Far East

3. Secondary School №143 for the provision of an equipped laboratory in which the company's employees worked on the project

4. Puryaev Dmitry Vitalievich for the help provided, motivation and shared experience.

5. Siberian State University named after M.F. Reshetnev for financial support

6. The Aquatics Palace of the of Siberian State University for the provision of a pool for testing ROV.

7. Parents of our employees for their support and encouragement

Links

Company employees used the following sources for their work:

1. Rules of MATE ROV Competition [Electronic resource]- http://files.materovcompetition.org/2021/2021_EXPLORER_Manual_8Mar2021.pdf

2. Structure. Interpreting bytes as binary data [Electronic resource] - https://docs.python.org/3/library/struct.html
3. Python sockets [Electronic resource] - https://habr.com/ru/post/149077/
4. Exploring Adafruit [Electronic resource] - https://learn.adafruit.com/16-channel-pwm-servo-driver?view=all
5. GitHub [Electronic resource] - https://github.com/Reinbert/pca9685
6. Open CV [Electronic resource] - https://docs.opencv.org/master/d6/d00/tutorial_py_root.html

Appendix

Safety protocol for working with ROV

Before starting

1. The working area is free (no objects to trip over)
2. The cable is deployed
3. The cable is connected and secured to the robot
4. Checking the tension of the cable connected to the robot
5. The flask with electronics is hermetically sealed
6. Electronics inspection for disconnected and damaged wires
7. Flask lids tightly closed
8. Nothing interferes with the work of the motors
9. Make sure that no one is near the engines (does not work with them, does not inspect)

Launch

1. The laptop and power supply are working properly
2. Warn company employees about power on for the robot
3. Power on the robot
4. Warn employees about testing of engines
5. Motor test (joystick movement corresponds to the engines)
6. Checking the operation of the camera and servo

In water

1. Check for leaks
2. If bubbles come out of the flask, immediately turn off the power, remove the robot and
3. Check for leaks

Leak test

1. Leak test is carried out with power off
2. Submerge the robot to the intended working depth of the ROV
3. Wait 5-10 minutes
4. Visually determine if there is no air escape
5. Bring the ROV to the surface
6. Carefully inspect the entire flask for the presence of water

Safety checklist

Stage	task	performance
Before starting	The working area is free (no objects to trip over)	
	The cable is deployed	
	The cable is connected and secured to the robot	
	Checking the tension of the cable connected to the robot	
	The flask with electronics is hermetically sealed	
	Electronics inspection for disconnected and damaged wires	
	Flask lids tightly closed	
	Nothing interferes with the work of the motors	
	Make sure that no one is near the engines(does not work with them, does not inspect)	
Launch	The laptop and power supply are working properly	
	Warn company employees about power on for the robot	
	Power on the robot	
	Warn employees about testing of motors Motor test (joystick movement corresponds to the motors)	
	Checking the operation of the camera and servo	
In water	Check for leaks	
	If bubbles come out of the flask, immediately turn off the power, remove the robot and check for leaks	

Leak test	Leak test is carried out with power off	
	Submerge the robot to the intended working depth of the ROV Wait 5-10 minutes	
	Visually determine if there is no air escape	
	Bring the ROV to the surface	
	Carefully inspect the entire flask for the presence of water	
Responsible	**Full name**	**Signature**