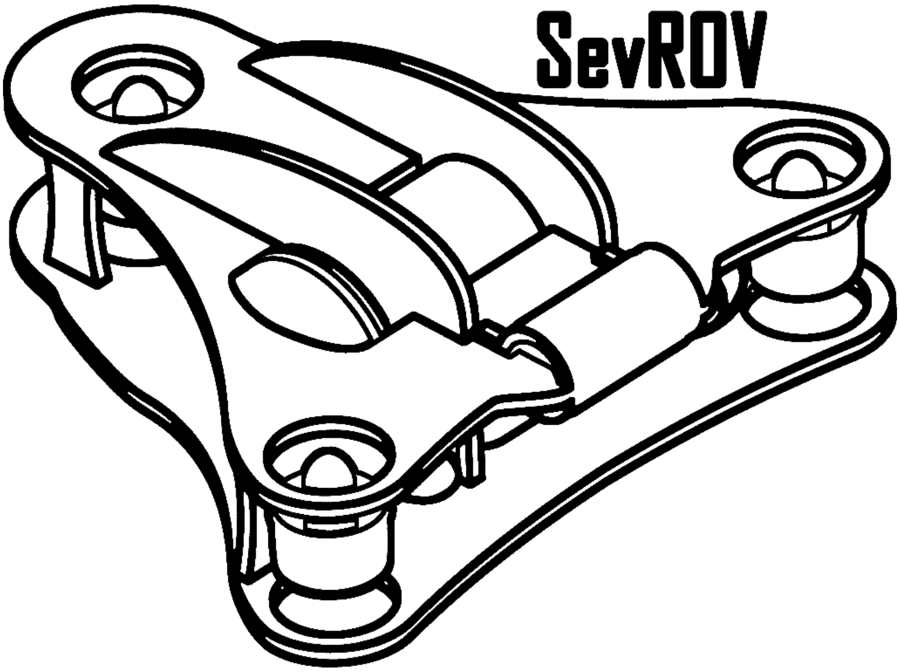
SevROV

Sevastopol State University, Russia

Mate 2021

Technical documentation



Team Members:

Igor Ermakov
    Team lead, technical lead

Yuri Balashov
    Software engineer

Darya Medvedeva
    Electrical engineer, copilot

Anastasiya Vorobeva
    Organization support, documentation

Mentors:

Alexey Kabanov
    Supervisor

Vadim Kramar
    Mentor

Table of Contents

Introduction

Abstract

SevROV - student group of the Sevastopol State University. In 2021, we held the MATE Russia-Far East Regional ROV Competition in our region, and this event prompted us to take part in the MATE ROV Competition 2021 in the Explorer class.

We started our ROV developments in 2019 with concept of ROV with Y-frame chassis. It was our first fully own-made ROV. Development of this ROV was a great challenge for us. Originally, we weren't aim for MATE ROV competition and trying to make a vehicle based on our knowledge and the components available at that time. In 2020 we took part in the all-Russian competition in marine robotics to test our solutions in practice and it showed the competitiveness of our ROV.

In this document, we will show our design decisions and how we achieve high maneuverability of our ROV only with 6 thrusters on it.

Mechanical design

Base idea

Our design is based on the idea of Y-frame chassis. This type of frame is common in aerial and mobile robotic, but rarely found in underwater robots. We consider to correct this injustice and make our own ROV with Y-frame. This frame has great possibilities: we can achieve controllability in 6 degrees of freedom with only 6 thrusters. This feature is usually achieved by suing 8 thrusters, so we have 25% of max power savings just from start. Negative side of Y-frame is lower speed and lower carrying capacity, but as practice later showed, the carrying capacity of our ROV turns out to be no worse than that of 8-trhruster analogues.

Second hypothetical idea is that with Y-frame we can better distribute mass of ROV with load of different cargo in manipulator. On figure 1 mass of cargo (m) on manipulator (E) moves center of masses of ROV further to front side thanks to which the entire mass of the vehicle with a load falls on the thrusters 1 and 2 with a small arm of forces, so their efficiency is rising. Along with this, the arm of the forces of the thruster 3 increases, which allows it to effectively control the pitch of ROV.

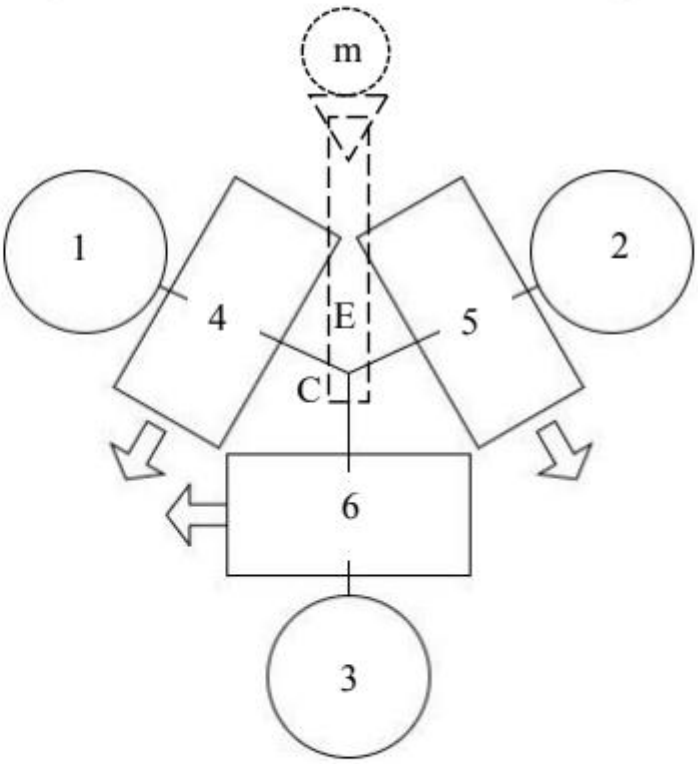


Fig. 1 – SevROV Y-frame composition scheme

Frame design

ROV development starts with designing of its frame. Frame need to be made of sheet polyethylene 10mm thick with joint-to-joint assembly and connect all mechanical parts of designed ROV.

Frame designing starts in CAD such as Autodesk Fusion 360 and first step is made schematic arrangement of main components: electronics unit, thrusters, and manipulator. The location of these components determines the size of the vehicle and its dimensions.

Next step is to make a 3D model of frame using dimensions of all elements and make full composition of ROV to check is ROV layout correct.

Fig. 2 – 3D model of chassis and full ROV composition in CAD program.

Final vehicle dimensions are 600x490x233

Final step for frame designing is making of cutting patterns for CNC machining,

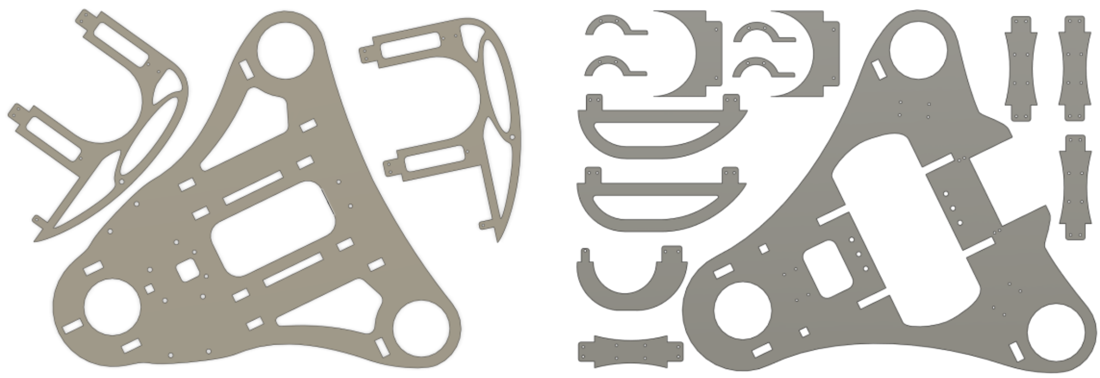


Fig. 3 – frame cutting patterns

Thrusters

In our ROV we using 2kgf thrusters(fig.4) based on brushless DC motors with built in electronic speed controllers (ESCs). We choose those thrusters because we have a some of them from our previous ROV and reuse of them was a great idea to save money. Great feature of this motors is that their ESCs are built in metal casing which contacts with water, so ESCs never overheating and can work on high load for a long time.

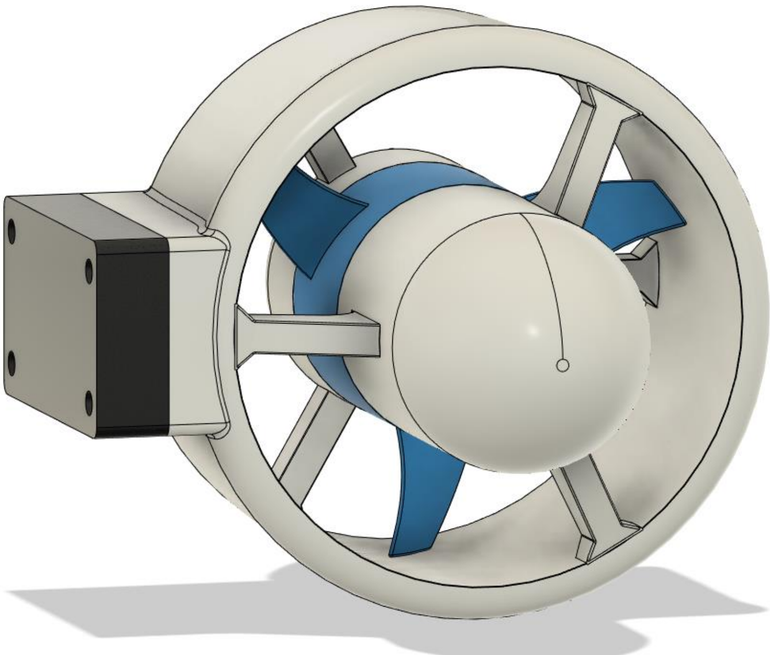


Fig.4 – thruster

Electronics Housing

For keep all electronics dry and safe underwater we consider to build waterproof casing for all electronics. Casing made with holes for connectors to connect all electronical components and tether. Casing has no windows so we need to use external camera.

Designing of casing for electronics was a one of biggest challenges of all development. It needs to be waterproof for at least 100 meters deep. We came to final design of cylindric chassis with two caps, one cap has all connectors for interfacing, second cap has only depth sensor and pressure relief valve/airtight testing valve. Valve on second cap is using only for ease of assembly and for tightness check on surface.

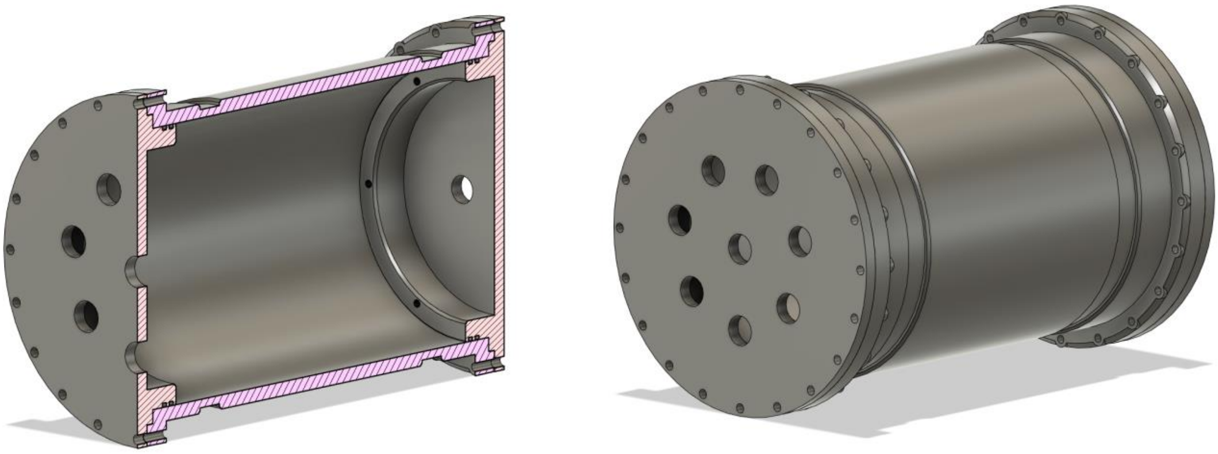


Fig 5 – waterproof casing

To seal casing, we using three O-rings on each side

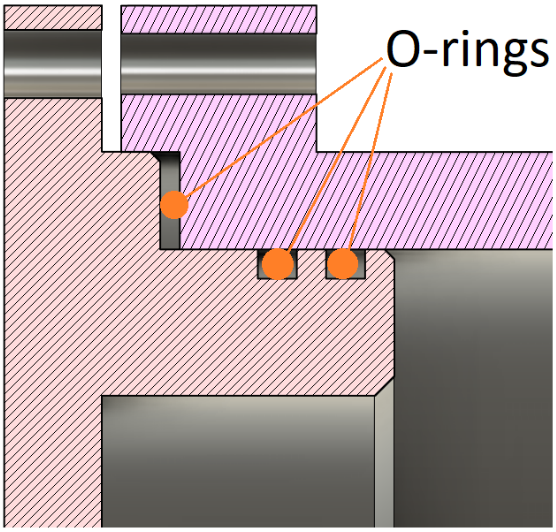


Fig. 6 – casing sealing

Camera

On our ROV we have to use external camera, so we consider to reuse camera for our previous ROV. This is a simple FPV camera in acrylic cylindric casing. It has a servo motor in it, which allows to rotate camera. Rotatable camera makes control of robot much easier.

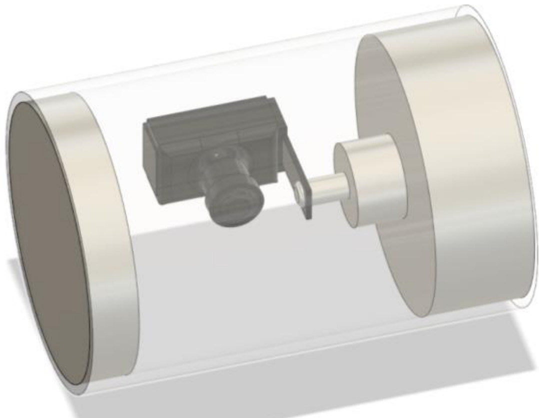


Fig. 7 – camera

Because our camera operates only with analog signal, we cant make any computer vision in our ROV and for future we will be change this camero to digital to be able compute video signal.

Manipulator

As many of others components, we reuse manipulator from previous ROV. This manipulator is controlled by simple two-channel dc motor driver (we using monster motor shield in our ROV) and control by voltage from 12v to 24v. It has big grip and can rotate on 360 degrees without wire twisting.

Fig. 8 – manipulator

Electronical design

Overview

Our team aimed for flexibility and ability to make improvements on fly, so we consider to use in our system server-client architecture. This architecture comes with Raspberry PI 3B+ on ROV side as server and laptop on surface as client.

As server Raspberry PI in ROV compute all data, send data to client side, and controls all components of ROV. Laptop only send controlling information from gamepad/joystick and shows video and information from ROV.

Topside Electronics

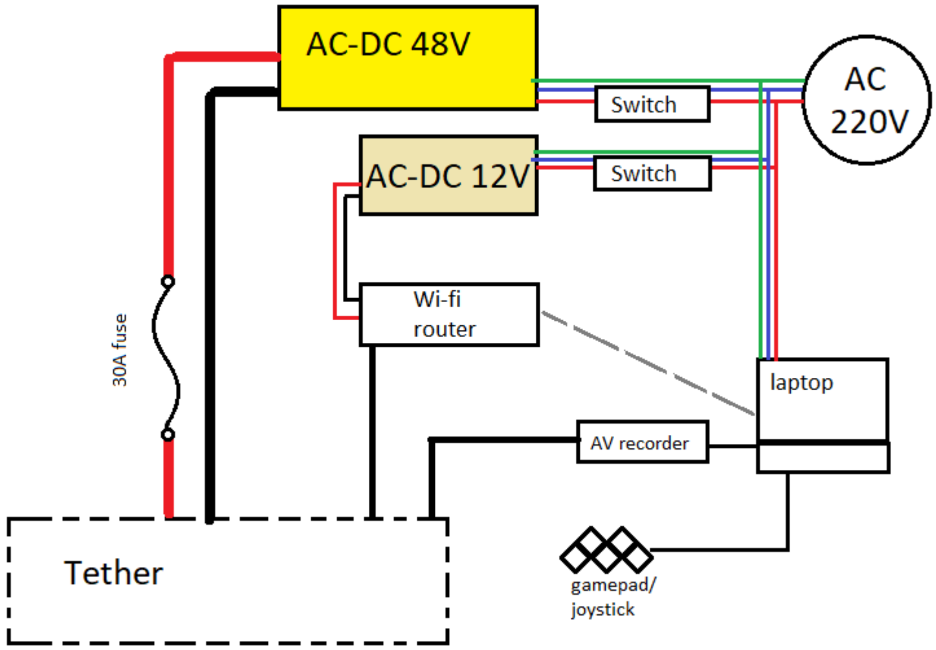


Fig. 9 – topside electronics

On surface we have two main components: laptop and surface control unit (SCU). SCU used to power ROV and make connection between ROV and laptop. Laptop is used for control ROV. Laptop connecting to SCU via Wi-Fi network or ethernet interface. Also, laptop getting video from ROV via USB recorder.

ROV side

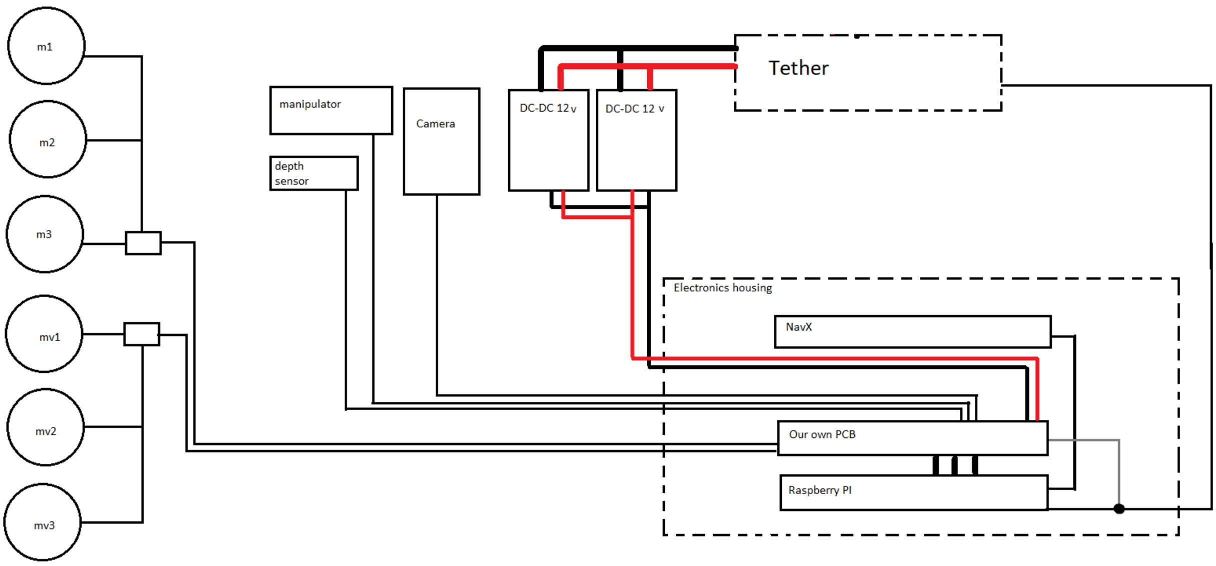
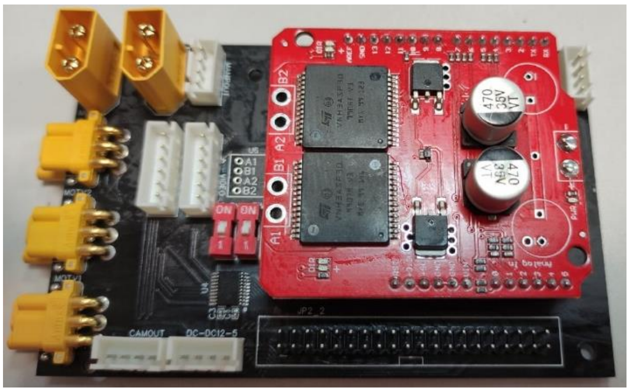


Fig. 10 – ROV electrical scheme

In core of the ROV electronics system we have Raspberry PI 3B+. To connect all electronic components, we have made special circuit board. This is a simple 2 layers board which connects all powers and signal. To make all working right on board we have logical level converter to pair 3.3v login on raspberry with 5v logic on other components.



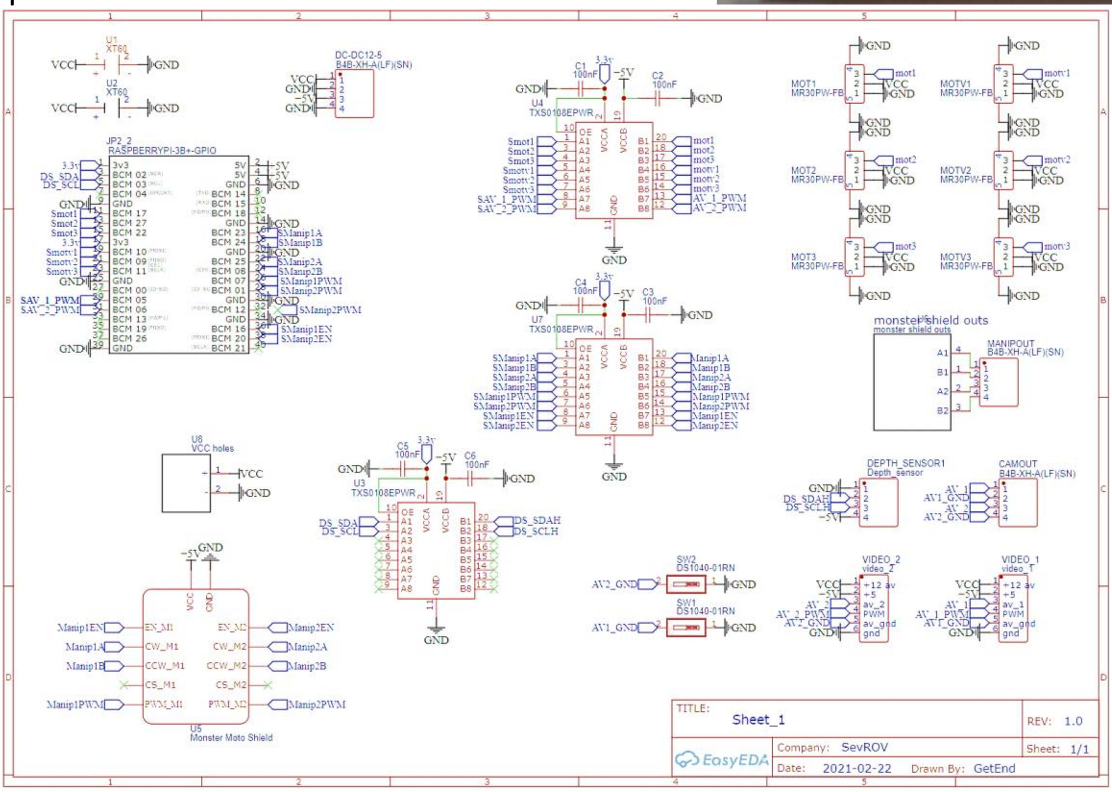


Fig. 11 – ROV board schematic

Program design

Main idea in creating software for SevROV is flexibility. We took one of the easiest ways to achieve this – control the ROV from PC. This allows us to always have possibility to make changes to programs and settings of ROV on fly and we don’t need to change whole firmware of any compute module to make little adjustment. We always can just connect to Raspberry by SSH or VNC and change any part of control system. It helps us a lot during tests.

Program part of the system for now can work only manually. Foremost this is because Y-frame needs precisely tuned control system and we have some troubles with stabilization. But for now, manual control works great.

Control system made up with two programs: Client for PC and server for Raspberry.

Fig. 12 – Client program without connection to ROV

Client program works with gamepad or joystick, AverMedia USB recorder and with our ROV via UDP protocol. Only requriment that system has – ROV and Client laptop need to be in one local network. This requirement is easily met by router in SCU.

Server side is the Python program without any user interface. It automaticly starts when raspberry boot up and wait for client to connect. After connection from client side server starts to send telemetry and eecute control comands. Server working with UDP, GPIO, I2C and USB to control the ROV. Stabilizaton subsystem is working even the client is not connected to ROV, so if we will have connectivity issues, vehicle will be stay stable.

Project management

We are student team of 4 people, and we have flat hierarchy in our work.

Roles are:

Igor Ermakov – Technical engineer, electrical engineer, programmer.

Yuriy Balashov – Program engineer.

Darya Medvedeva – Electrical engineer.

Anastasiya Vorobeva – documentation, organization support.

We started work on this project in 2019. And we set one big requirement – we need to use only parts, that we already have from previous ROV. So main expenses were for electronics housing and electronic components.

Table 1 - expenses

Item	Type	Amount	qty.	Cost
Thrusters	re-used	200	6	1200
HDPE for frame	re-used	215	1	215
Manipulator	re-used	410	1	410
Camera	re-used	95	1	95
DC converters	re-used	69	2	138
Electronics Housing	donated	684	1	684
PCBs and electronics	purchased	352	1	352
Wi-Fi router	purchased	20	1	20
gamepad	purchased	50	1	50
Total	3164			
Total spend	422			