# Task-oriented Design of an Underwater Vehicle for Environmental Monitoring in The Baltic Sea.

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## I. INTRODUCTION

Our goal is to design a vehicle for environmental monitoring in The Baltic Sea that is first and foremost meant for monitoring of underwater vegetation and benthic morphology.

The Baltic Sea is one of the most severely polluted seas in the world. The extent and distribution of underwater vegetation gives a lot of information about pollution, climatic conditions, ice conditions etc., therefore vegetation is monitored regularly. At present underwater monitoring is done by divers, which is laborious, expensive and dangerous.

We have designed a prototype of a vehicle that is equipped with an underwater camera and is meant to replace the human diver. In addition to hydrobiological surveys the vehicle can also be used to record other environmental parameters like water temperature, pH-level, salt content, etc. Since the device is equipped with an underwater camera it can also be used for underwater inspection e.g. at rescue operations, construction work, etc. in shallow waters, including inland water bodies.

### *A. Task description*

The requirements determining our vehicle design can be divided into two large categories. The first category consists of environmental factors that are unique to the The Baltic Sea. The second category is the human and task specific factors. In the following subsections we describe both of the categories closer.

### *B. Environmental factors*

The Baltic Sea is different from subtropical and tropical seas or exposed seas like Nordic Sea. The factors influencing our choices of the vehicle's design are the following:

*1) Depth:* The Baltic Sea is relatively shallow and therefore the underwater vehicles do not have to operate under high pressure.

*2) Turbidity:* water is very turbid due to floating detritus and therefore visibility is very low.

*3) Extension of vegetation:* due to low visibility, the euphotic zone (the zone of penetration of light into the water column) is rather narrow and therefore the vegetation is limited to the costal regions in the depth down to approximately 20m. The regions of interest for environmental monitoring are usually near the coastline in the depth from 1m to 6m.

*4) Properties of the seabed:* most of the seabed in the depth of interest is covered with mud or small particles of zoo- and phytoplankton that has settled down and is extremely volatile.

*5) Human inhabitancy:* The Baltic Sea is under a severe anthrophic pressure. Costal regions that are especially interesting for monitoring are full of harbours, beaches, fishing nets, dense surface traffic, etc.

### *C. Human- and task specific factors*

This research is strongly demand-driven and therefore we focus on satisfying the requirements of the end users, which are in the first place environmental scientists. The human and task specific factors that influence our vehicle design are the following:

*1) Main functions:* the main function of the device is to facilitate environmental monitoring. The highest priority is to facilitate monitoring of underwater vegetation.

*2) Additional functions:* if possible, the device should also permit measuring other environmental parameters, like temperature, pressure, salt content and make it possible to correlate these parameters with hydrobiological data. It could also be used for other type of benthic surveys and diving under ice in winter. Alternatively, the vehicle could be used for environmental monitoring of shallow inland water bodies (rivers, lakes and bogs).

*3) Operational requirements:* the device should be portable, preferably operated by one person only; it should support storing, processing and mapping of environmental data.

*4) Cost requirements:* since the vehicles can occasionally be lost, their cost has to be kept as low as possible.

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## II. DESIGN CONCEPT

### *A. Semiautonomous and remotely operated modes*

Current AUVs and ROVs are mostly operated from ships and often weight hundreds of kilos or tons. This is impossible in The Baltic Sea; no ship can enter the zones of interest to biologists. Therefore our device must be light enough to operate from an inflatable boat.

Underwater navigation and mapping is still a field of intensive research. Despite of several emerging solution, the methods of underwater navigation are still under development. In addition, a fully autonomous vehicle must carry its own batteries. The batteries have to be charged often and they increase the weight of the vehicle. A fully autonomous vehicle can be lost more certainly (environmental researchers report every year loss or theft of a great deal of their equipment). Considering these disadvantages we propose a semiautonomous vehicle that can be operated in two modes:

*1) Towing mode:* in this mode the vehicle is towed behind a boat or a ship. With the help of a bow sonar it adjusts its height from the bottom. The power supply and localization unit are on the surface as well as the data storage for gathered data. The towing mode permits covering large distances at speed. At present, benthic surveys are often done by towing a diver behind a boat. According to preliminary calculations, replacing the diver with a vehicle will be approximately 10 times more efficient.

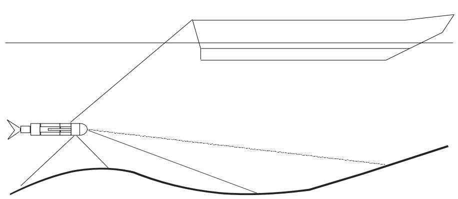

Fig. 1. Using the vehicle in a towing mode.

*2) Remote control mode:* the operator can manually drive the vehicle. This mode requires more control surfaces for the greater manoeuvrability. This mode can be used for closer inspection of underwater sites or diving under ice.

### *B. Fin-like control surfaces*

Underwater vehicles almost exclusively use thrusters for locomotion. The disadvantage of thrusters is that they create strong turbulence. Our experiments show that at the moment the thrusters are switched on, visibility becomes practically zero and it takes a long time before the extremely volatile detritus settles down again. This feature makes it difficult to design a vehicle with thrusters that meet the requirements of the task description. On the one hand visibility is very low. Therefore a vehicle that is used for benthic surveys, like monitoring underwater vegetation or bottom morphology, has to be close to the seabed.

We therefore have decided to use elevators instead of the thrusters in a tow mode to control the depth of the vehicle and additional rudders for yaw stability.

In the future, we aim at using the caudal-fin like propulsion in the remotely controlled mode and pectoral-fin like motion for stability and manoeuvrability, but this is still a topic for future research.

## III. DESCRIPTION OF THE VEHICLE

The layout of the interior of the vehicle is represented in Fig. 2. Since our aim is to keep the cost of the vehicle low, the prototype is built from off-the shelf components that are easily replaceable.

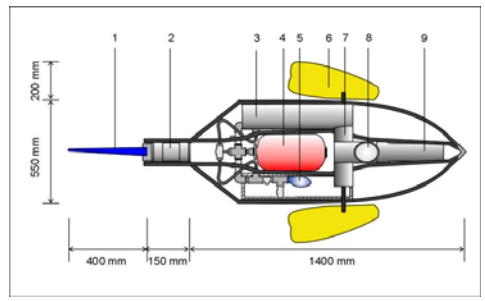


Fig. 2. Internal layout of the vehicle
(1-fin, 2-stepper, 3-PVC tube, 4-compressed air tank, 5-rubber tank, 6-fin, 7-stepper, 8-camera, 9-batteries and electronics)

Fig. 3. Vehicle prototype.

At present we have built the first prototype of the vehicle, partially implemented the control system and tested the preliminary prototype in a pool (Fig. 3). The test results show that the robot is functional but its efficiency can be increased.

These preliminary test results can be used to redesign the robot. According to the test results and preliminary calculations we are rebuilding the prototype and implementing control algorithms to incorporate sensor readings and control the vehicle in a feedback loop.

The first field tests on the sea are scheduled for the end of June. For the deadline of the final paper we expect to have more test data from the field tests evaluating the performance of the vehicle.