UNDERWATER VEHICLES IN THE RESEARCH WORK OF SZCZECIN UNIVERSITIES – SYSTEMS AND APPLICATIONS

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ABSTRACT

The article presents the scope of research and application work on unmanned remotely operated deep-sea vehicle systems carried out at the then Szczecin University of Technology (now the West Pomeranian University of Technology in Szczecin). The work culminated in the construction of said systems and subsequent pioneering underwater work using them, implemented in cooperation with maritime industry establishments.
Keywords: deep-sea technology, remobely operated vehicles, manned deep-sea vehicles.

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INTRODUCTION

The 1990s were a period of development of unmanned remotely operated deep-sea vehicles (ROVs) at the Faculty of Marine Technology (since 2011 – Faculty of Maritime Technology and Transport at the West Pomeranian University of Technology in Szczecin) and cooperation with universities and maritime institutions in the application of these systems.

The research was extended to include conceptual design of ROV systems, design and performance analysis of vehicle subsystems, issues of forecasting and realisation of specific vehicle motion properties, construction of the ROV systems and applications of the systems developed [1,2,3,4,5,7].

The article is a continuation of the subject presented in a separate paper entitled "Underwater vehicles in research works of Szczecin universities – projects".

AREA AND SCOPE OF RESEARCH WORK IN THE FIELD OF UNDERWATER TECHNOLOGY

The need to explore bodies of water in order to identify submerged technical objects such as pipelines, cables, metal objects and, in particular, remnants of the First and Second World Wars, including military assets in the form of ammunition and combat gas containers, was the trigger for the research and development of underwater vehicle systems with such a purpose.

The research work involved the design and construction of ROVs that guaranteed distance of humans from dangerous sites, the possibility of long-term operation without physiological, energy and time constraints, and the replacement of costly manned vehicle missions and the employment of divers, which at considerable depths usually requires an extensive technical and medical base.

Table 1 lists the ROV systems designed and built at the Marine Technology Department (the author acted as project manager). Two of them, using *NUR* and *MAGIS* vehicles for underwater tasks, found practical application in deep-sea tasks carried out for maritime institutions [6]. These systems continue to be in operation today.

Tab. 1

Underwater vehicle systems built at the Marine Technology Department.

No.	**System name**	**Vehicle name**	**Vehicle characteristics** working depth [m] shape/form purpose	dimensions [mm] propellers weight [kg]	**Research/ construction period**
1	SMP-50	*KRAB I*	50 frame structure inspection	1200x1270x700 5 propellers 62	1991-1993
2	SWOT-150	*KRAB II*	150 frame structure inspection, monitoring	1200x1270x700 5 propellers 70	1993-1995
3	MZSPG	*PNP-50*	50 frame structure inspection, search	1000x800x600 5 propellers 50	1997 projekt
4	TODS-400	*MAGIS*	400 shape of the spindle research equipment pilotage system inspection, measurements, simple works	2250x760x600 6 propellers 120	1994-1999
5	SMG	*MAGIS*	as above, system miniaturisation change in vehicle equipment configuration change in power of transverse propellers control system automation		2004-2007

SMP/SWOT MONITORING SYSTEMS

The system and equipment built at the Underwater Engineering Unit at the Marine Technology Department were designed for use in the Baltic Sea, port basins, including the basins of former military bases, as well as in inland reservoirs. The equipment was also tasked with determining the degree of ecological harmfulness of the objects deposited and developing a method of recording and logging them for further work aimed at excavating or neutralising the deposited finds. The use of the system also included the assessment of risks during dredging of reservoirs and fairways.

The SMP Underwater Monitoring System used the *KRAB I* unmanned underwater vehicle as the apparatus carrier, which was designed with the participation of the Submar Design and Service Company and built in cooperation with the Canadian company Hydrobotics Engineering Inc. which was necessary due to the embargo on the supply of specialised equipment for the vehicle to Poland. The SMP consisted of two facilities:

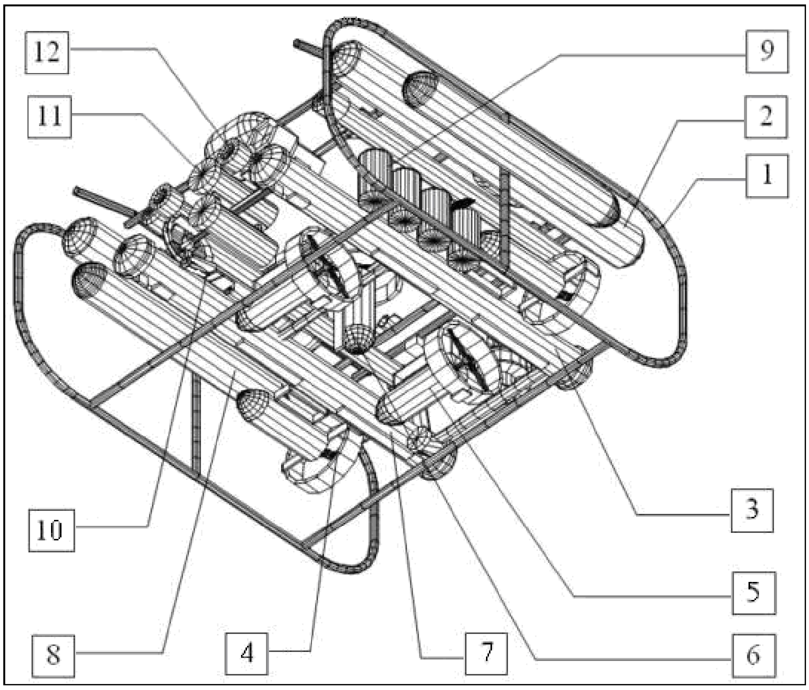
- a control and research station containing: control console, control panel, monitors, monitoring data visualisation subsystem,
- the *KRAB I* underwater equipment carrier with a support structure made of aluminium tubes, containing equipment placed in pressure containers, Fig. 1, Table 2.

The vehicle was subsequently upgraded to the *KRAB II* version, Fig. 1, Fig. 2, Table 2, characterised by the expansion of the vehicle and equipping it with additional devices for monitoring the state of the aquatic environment (measuring probe for physicochemical parameters of water), water sampling device, magnetometer, echo sounder for measuring the distance from the bottom and water surface. The *KRAB II* vehicle, which is the equipment carrier for the new SWOT Technical Object Detection System, has successfully passed field tests and the system has found commercial applications. Inspection work can be carried out with this system down to a depth of 150 m, and measurements of the physical and chemical properties of the water down to a depth of 50 m.

Tab. 2

Technical characteristics of the *KRAB I* and *KRAB II* underwater vehicles.

No.	Specification	*KRAB I* in SMP system	*KRAB II* in SWOT system
1	Weight [kg]	70	90
2	Dimensions [mm]	1200x1270x700 mm	
3	Difference in the height of centres of buoyancy and gravity [mm]	40	50
3	Working depth [m]	50	150
4	Speed [m/sec]	2,0	1,5
5	Load-bearing structure	rectangular frame made of aluminium tubes	
6	Proppelers, configuration	4 longitudinal, 1 vertical	2 longitudinal, 2 transverse, 1 vertical
7	Power supply	220 V/50Hz	
8	Equipment	colour and monochrome TV camera, tilting platform for cameras and lights 2x150 W, single-function joystick magnetic compass, depth gauge.	colour and monochrome TV camera, tilting platform for cameras and lights 4x150 W, single-function manipulator-grip, magnetic compass, depth gauge, measuring probe for physical-chemical water parameters. Optionally: magnetometer, water sampling device, echo sounder to measure distance from the bottom and water surface.



1 - frame	7 - electronics container
2 - buoyancy container	8 - measuring head
3 - buoyancy container	9 - water probe
4 - longitudinal propeller	10 - manipulator
5 - transverse propeller	11 - tv camera
6 - vertical propeller	12 - floodlight

Fig. 1 Configuration of the *KRAB II* underwater vehicle – view from below.

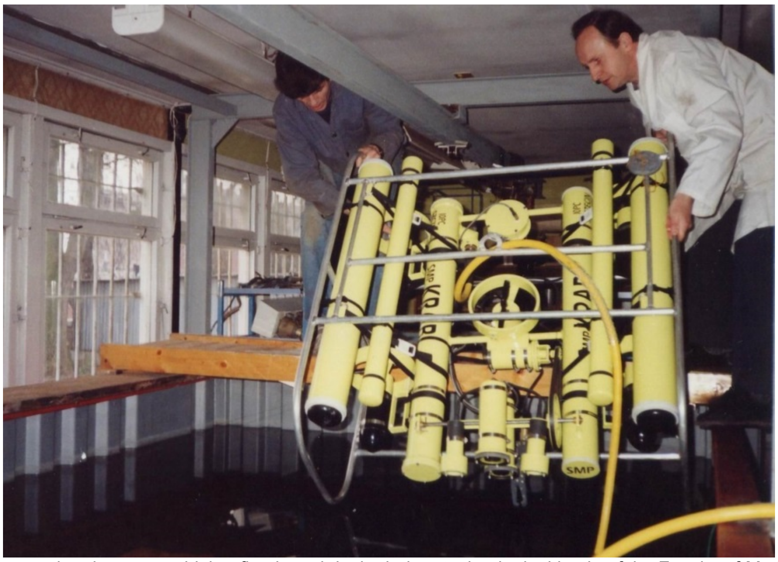


Fig. 2 KRAB I unmanned remotely operated underwater vehicle - first launch in the indoor technological basin of the Faculty of Marine Engineering of the Szczecin University of Technology.

Fig. 3 Unmanned remotely operated underwater vehicle (ROV) *KRAB II* equipped with laser tracer L for the study of the vehicle's trajectory.

Implemented in the Ship Technology Department at the Faculty of Marine Technology, Szczecin University of Technology: Research Project of the Committee for Scientific Research No. 7 0117 91 01 entitled "Systems and Equipment for Underwater Works Technology," 1991-1993 and Research Project of the Committee for Scientific Research No. 9 S604 063 04 entitled "SWOT Systems for Detection of Technical Objects in Water," 1993-1995.

Research team: Tadeusz Graczyk, Leszek Bednarski, Bartłomiej Jakus, Henryk Kierul, Mariusz Matejski, Łukasz Piskorski, Eugeniusz Skrzymowski, Władysław Skurski, Zbigniew Szymczyk, Antoni Wiliński.

SEARCHING UNDERWATER CARRIER *PNP-50*

The design of the PNP-50 searching underwater carrier vehicle was developed to meet the needs of the Navy and the Police in performing inspections of dangerous objects and searches for explosive charges – mainly in coastal and inland waters to a depth of 50 m, Fig. 3. The design draws on the team's experience gained from the construction of the SMP/SWOT system and anti-terrorist field tests using the *KRAB II* vehicle.

Assumptions were developed for the miniaturisation of the vehicle system and a procedure for its use in inspection and anti-terrorist operations.

Implementation in the Ship Technology Department at the Faculty of Maritime Technology, Szczecin University of Technology: 1997.

Research team: Tadeusz Graczyk, Mariusz Matejski, Łukasz Piskorski, Władysław Skurski.

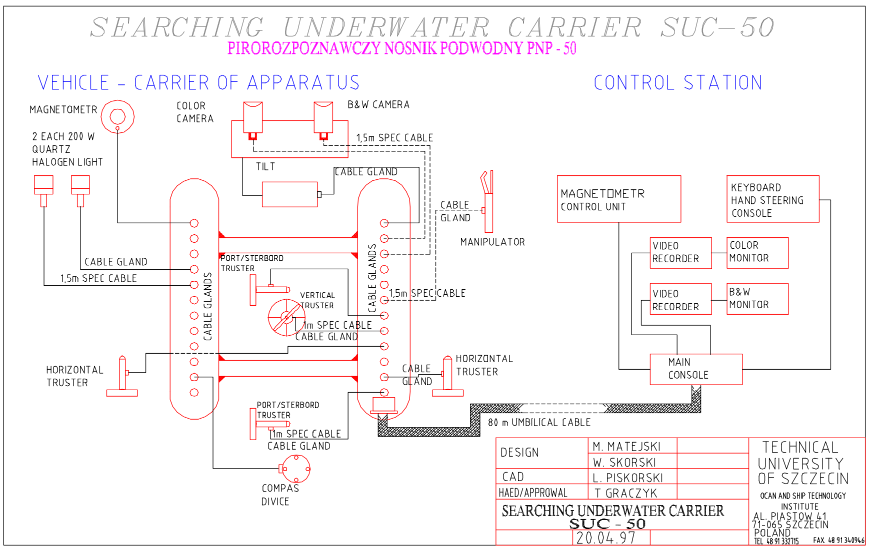


Fig. 4 *PNP-50* searching underwater carrier – block diagram of the modification of the *KRAB II* vehicle system for anti-terrorist operations.

TODS-400 TECHNICAL OBJECT DETECTION SYSTEM

Research carried out at the Marine Technology Department by the Underwater Technology Unit included: monitoring of lakes, surveys of fairways, harbour basins, archaeological work in selected areas of the Baltic, investigations of the technical condition of oil rigs, surveys of artificial reefs in Polish territorial waters, etc. The results of these studies and the team's research work in the field of marine environment protection were used to design and build a universal tool for surveying the coastal zone and deep-water regions of the Baltic Sea, i.e. the TODS-400 (Technical Object Detection System), based on Phare European funds, Fig. 4.

The TODS-400 system consists of the following components:

- the *MAGIS* underwater carrier, the technical specifications of which are shown in Fig. 6 and Table 3,
- a mobile command and control station in a truck trailer containing: power distribution module, 100 and 400 m cable reels, control console, remote control console.

The TODS-400 system uses fibre-optic technology to transmit control and video signals.

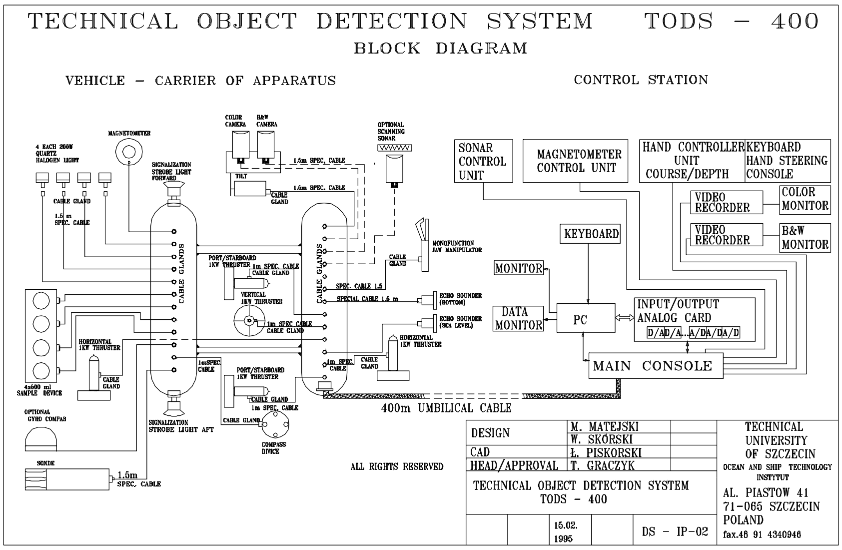
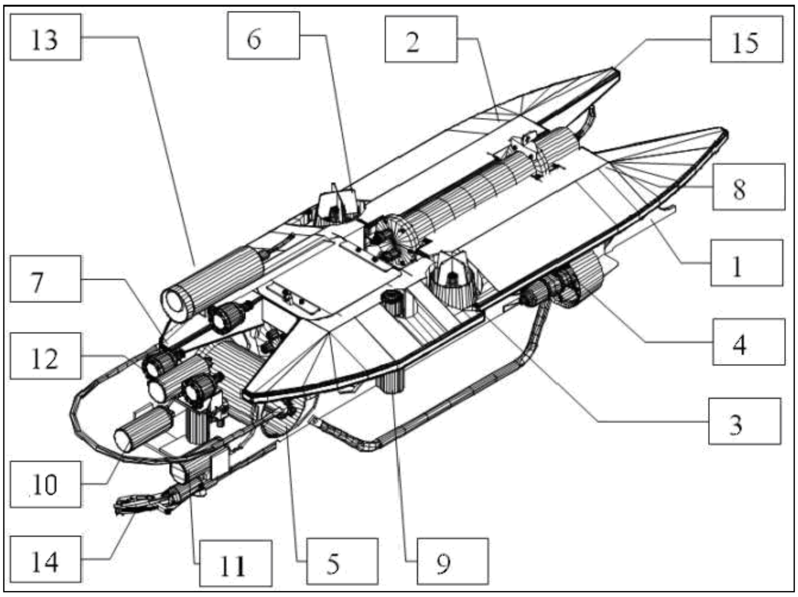


Fig. 5. Block diagram of the TODS-400 underwater system.

Tab. 3

Technical characteristics of the *MAGIS* vehicle.

No.	Specification	Description
1	Weight [kg]	120
2	Dimensions [mm]	2250x760x600
3	Difference in the height of centres of buoyancy and gravity [mm]	50
3	Working depth [m]	400
4	Speed [m/sec]	2,5
5	Hull shape, structure	spindle, frame – aluminium plates, pressure containers – PVC, floats – laminated polystyrene
6	Propellers, configuration	2 longitudinal, 2 transverse, 2 vertical
7	Power supply	3x380 V/50Hz
8	Equipment	colour TV camera and 2 floodlights with tilt mechanism, black and white fixed TV camera, camera and strobe light, dual-function manipulator – grip, rotation, hydro-acoustic transmitter, compass, pressure gauge water property measuring probe



1 - vehicle frame | 2 - buoyancy module | 3 - electronics container
4 - longitudinal propeller | 5 - transverse propeller | 6 - vertical propeller
7 - floodlight | 8 - compass (invisible) | 9 - hydroacoustic transmitter
10 - photo camera | 11 - strobe light | 12 - colour tv camera
13 - black and white tve camera | 14 - manipulator | 15 - umbilical cable

Fig. 6 The *MAGIS* vehicle configuration.

Implemented at the Ship Technology Department, Faculty of Marine Engineering, Szczecin University of Technology: EU Project Phare PL 9409-01-03 titled "The Modification of the Technical Objects Detection System (TODS-400) to Specify Pollution in Near-Bottom Zone of the Baltic Sea," Cross Border Co-Operation Programme Poland-Denmark, Coastal Monitoring, 1994-1999 and Project No. 5/97/MN-PO/D titled "Contamination Detection System in the Near-Bottom Zone of the Baltic Sea with Modification," Voivodship Fund for Environmental Protection and Water Management in Szczecin, 1997.

Research team: Tadeusz Graczyk, Sławomir Jaszczak, Henryk Kierul, Mariusz Matejski, Łukasz Piskorski, Władysław Skurski, Włodzimierz Stawarz, Zbigniew Szymczyk.

SMG UNDERWATER MONITORING SYSTEM

The SMG underwater monitoring system for hazardous conditions, Fig. 7,8,9 built within the framework of a research project of the Ministry of Education and Science, is based on the concept of the TODS system, which is not sufficiently mobile for certain applications (large weight and volume of system modules, operation by four people) and has limited capabilities for investigating the state of the aquatic environment. The SMG system uses a modified *MAGIS* vehicle designed to perform underwater tasks to depths of 400 m.

The modification of the former TODS system involved adapting it to the expectations of the users, which were pinpointed after gathering experience from the field tests and previous applications. In particular, it entailed:

- increasing the mobility of the system through miniaturisation of components, such as the power distribution module,
- equipping the system with umbilical cable reels of 100 and 400 m in length,
- modernisation of the propulsion system – changing the power distribution in the propeller system to increase the power of the longitudinal propellers at the expense of reducing the power of the transverse propellers,
- application of automatic vehicle motion control – stabilisation of the course and depth,
- use of modern storage media for data recording,
- extension of the possibilities of measuring the state of the environment - identification of military remains.

Fig. 7 The underwater vehicle *MAGIS* during technical condition surveys of the floating dock at the Szczecin Shiprepair Yard Gryfia.

Fig. 8 Testing of the properties of the *MAGIS* underwater vehicle in the technological pool of the Ship Technology Department of the Szczecin University of Technology.

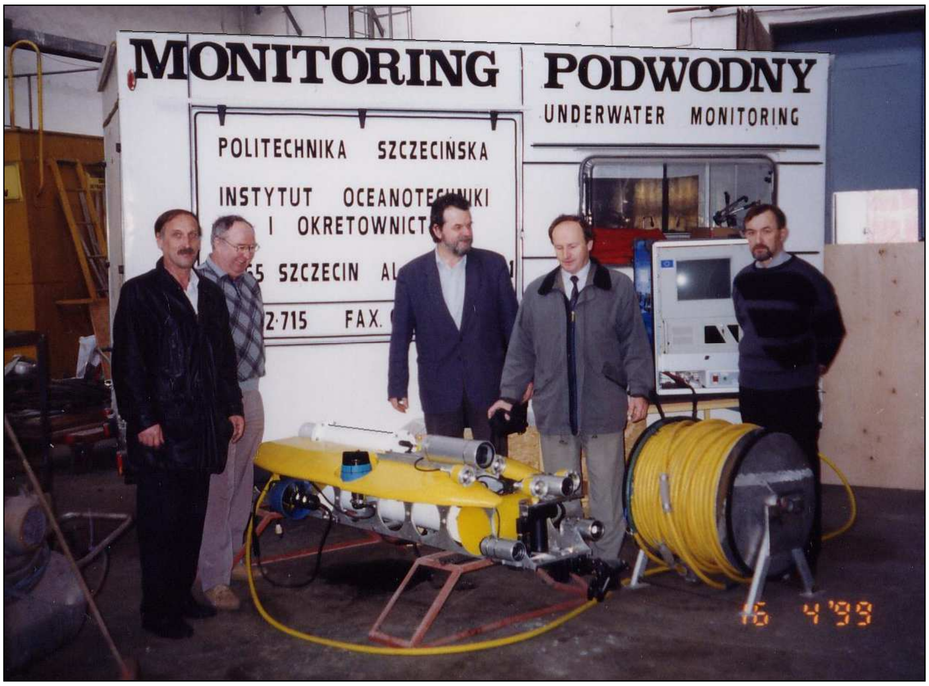


Fig. 9 Underwater Monitoring System and the design and research team of the Faculty of Marine Engineering, Szczecin University of Technology. From the left: Zbigniew Szymczyk, Henryk Kierul, Władyslaw Skórski, Tadeusz Graczyk, Mariusz Matejski.

Implemented at the Ship Technology Department, Faculty of Marine Engineering, Szczecin University of Technology: Research Project of the Ministry of Education and Science No. 4 T12C 020 26 entitled "Underwater Monitoring System for Hazardous Conditions,", 2004-2007.

Research team: Tadeusz Graczyk, Sławomir Jaszczak, Henryk Kierul, Mariusz Matejski, Łukasz Piskorski, Władysław Skurski, Włodzimierz Stawarz, Zbigniew Szymczyk.

COOPERATION BETWEEN INSTITUTIONS ON UNDERWATER RESEARCH

Research, design and implementation work on underwater vehicle systems was carried out at the Szczecin University of Technology, and later at the West Pomeranian University of Technology in Szczecin. Some design work, model tests and especially application tests on vehicle systems were carried out in cooperation with other universities and institutions mainly in the maritime industry. These included:

- Academy of Agriculture in Szczecin – Faculty of Food Sciences and Fisheries,
- Maritime Academy in Szczecin,
- University of Szczecin – Department of Archaeology,
- Gdańsk University of Technology – Faculty of Ocean Engineering and Shipbuilding,
- Provincial Office in Szczecin – Environmental Protection Division,
- Polish Navy – the 8th Flotilla of Coastal Defence in Świnoujście,
- Naval Academy in Gdynia – Mechanical and Electrical Department,
- Design and Service Company Submar in Gdynia,
- Ship Technology Centre in Gdańs,
- Central Maritime Museum in Gdańsk,
- Petrobaltic Oil and Gas Exploration and Exploitation Company in Gdańsk,
- Szczecin Shipyard,
- Szczecin Shiprepair Yard Gryfia,
- Bumar Hydroma Building Machinery Factory in Szczecin,
- Precision Mechanics Institute in Warsaw,
- Police Headquarters in Warsaw,
- Karkonoskie Zakłady Maszyn Elektrycznych [Karkonosze Electrical Machinery Works] in Piechowice,
- Hydrobotics Engineering Inc. w Ajax, Canada,
- Hytec in Montpellier, France,
- diving service companies specialising in underwater works.

Application studies included observation and monitoring of underwater facilities in the Baltic Sea and lakes. Assessments were made of the condition of the artificial reef in the Szczecin Lagoon and the mouth of the Piastowski Channel, assessments of the technical condition of the oil extraction tower and the condition of the hull plating of the ship's propulsion and steering gear, assessments of the condition of the floating dock and the docking depth. A successful search for wrecks and military objects in the Pomeranian Bay and Szczecin Lagoon was carried out. Inspections of harbour aquatoriums, quay support structures and other hydrotechnical facilities, a survey of the water intake and power plant intakes were carried out. Searches were undertaken for lost objects in the lakes. Observations of marine and lake flora and fauna were performed. Water sampling and testing was carried out. Divers were assisted in underwater works.

CONCLUSION

In terms of theoretical work, a structured basis for research in the field of oceanotechnical equipment design was established. A methodology was developed for the design of unmanned remotely operated underwater vehicles (BZSPG). In view of the lack of access to design data for systems offered on the market, limited by companies, a proprietary design algorithm was applied for the *MAGIS* vehicle system, allowing the use of the designer's expanding body of experience and the developing state of the art. The result of such a procedure is the possibility to build a vehicle meeting the adopted assumptions, with specific performance characteristics that satisfy the future user, but also enable the vehicle to be built in the technical conditions within the capabilities of the designer and manufacturer.

The result of the practical part of the research work is the construction of four operational BZSPG systems (Underwater Monitoring System SMP – *KRAB I*, SWOT Technical Object Detection System – *KRAB II*, Technical Object Detection System TODS-400 – *MAGIS*, and Underwater Monitoring System SMG – *MAGIS*), using which underwater works were carried out for institutions related to maritime economy. Two of the SWOT and SMG systems continue to be used today.

The result of research popularisation is more than 250 publications by the author and close collaborators involved in research in the area of underwater technology in technical journals, conference materials and book editions.

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