Application of Autonomous Remotely Operated, Vehicles for Detailed Exploration of Mineral Deposits

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Abstract

Various tools are needed for mineral deposits investigation. Different types of free fall, bounce and suspended grabbers are widely used nowadays. Autonomous ROV with ability of collecting nodule samples seems to be the best tool for detailed exploration of mineral site. Geologist will be able to get detailed information regarding sea bottom characteristics, nodule density and metal content in precisely located points. Consequently, decision making and risk analysis will be improved.

The proposed system for detailed exploration of the mineral deposit consists of two autonomous submersible crafts which work in continuous manner (8 -12 h cruise). While collecting mineral samples (up to 50 kg per dive) TV pictures of the samples are transmitted to the geologist giving him ability to collect the most promising mineral samples. The System is relatively light and compact. Control and storage containers enable to mount the system on the board vessel of opportunity with adequate deck space.

We observe continuous and rapidly growing interest in deep sea mineral deposits. Manganese and cobalt rich nodules as well as polymetalic sulfides seems to be promising source of raw materials in coming decade. Quite impressive number of companies and research institutions carries out feasibility and applied studies in this field. Some prototypes of the first generation exploration and mining equipment have been produced. Successful application of EPAULARD unmanned submersible is best example of an exploration system development. [5]

Prospects of commercial exploration of the mineral deposit creates needs for detailed investigation of the mining site using various technical means (Fig. 1). There is no doubt that remotely operated vehicles (ROVs) will perform vast number of typical and specific underwater missions. Some tests with unmanned submersibles had been performed. However, there is only a few information regarding deepsea ROVs operations and problems encountered. Experience with Woods Hole ARGO-JASON ROVs is best example of capabilities of teleoperated work and observation system.

Fig. 1 Remotely operated vehicles for detailed exploration of the deep sea mineral deposits

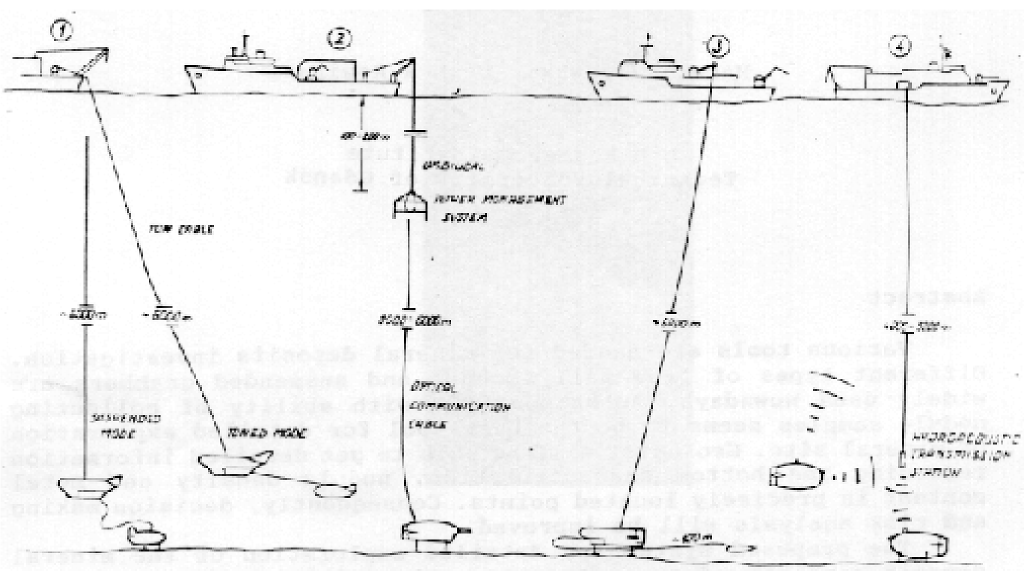
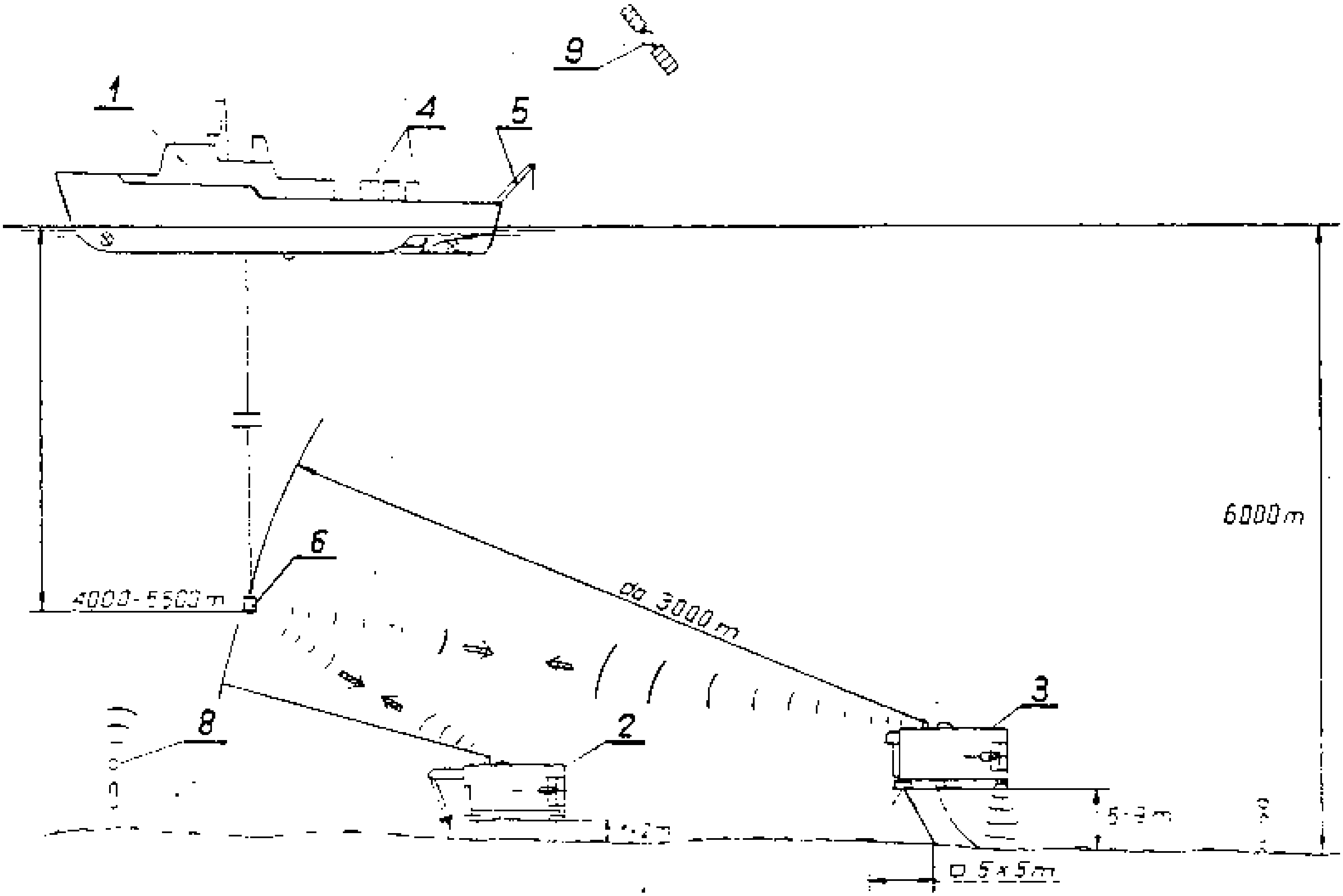


Fig. 2 "NODULE' Exploration System - principle of operation.



Financial problems are crucial for the advanced ROV system design and construction. Development and construction cost of the submersible can be reduced drastically by limiting number of functions to be performed by submersible itself. System reliability, cost effectiveness as well as exploitation cost reduction could be achieved this way. Good example of reliability and cost saving device is "boomerang" free fall sample grabber. Almost random way of collecting nodule samples could be accepted in today scientific research but it seems to be not enough efficient for commercial exploration. Autonomous submersibles/ manned and unmanned could be used for more complex tests and measurements, giving man an opportunity to perform required task itself or in telepresence manner. Taking into consideration current experience collected from operational use of underwater vehicles (ALVIN, MIR, GEMINI, EPAULARD), their suitability for detailed exploration of the promising mineral rich areas and future mining sites could not be easily questioned. However, manned submersibles applications are limited because of very high cost of development (20-70 mln US$) and exploitation- Their aviability is thus limited and it is almost sure that only limited number of new submersibles with minimum 4000m depth capability will enter into operational service in coming years.

Unmanned submersibles appears to be the best solution of the of problem of the detailed exploration of the mineral deposits. The following tasks can be performed by the unmanned autonomous remotely operated vehicles (AROV's) equipped with "relatively simple" artificial intelligence circuits.

- mapping of deposits area
- determination of concentration of the minerals in selected points of the exploration site
- determination physical and chemical properties of the bottom sediments
- collection of the most interesting mineral samples

The NODULE exploration vehicle system

A feasibility study for determination basic characteristics and financial parameters of a technical system for detailed exploration of Fe-Mn nodule deposits had been undertaken in Ship Research Institute, Technical University of Gdansk. Moreover, technical as well as economical problems related to the proposed system development had been also analyzed.

Basic design parameters of a device for geological exploration of nodule deposits are :

- maximal working depth 6000 m

- useful payload up to 50 kg of nodule samples

- flexible work tools package

After analysis of different mission profiles and mission tasks a concept of specialized AROV system had been created. The system consists of two autonomous submersible vehicles control room, maintenance workshop and operational storage and spare parts all contained in five 20' ISO containers. So designed system could be deployed on any craft of opportunity with sufficient deck space and launching crane or A-frame.

System Operation

Basic principle of the system operation is shown in Fig. 2. Two AROV's working in continuous manner (18 - 24 h a day) allow the most efficient exploration of the nodule deposits area. Almost continuous way of collecting detailed information permits to reduce total cost of gathering exploration data.

From operational point of view most interesting is daily information output. For four missions per day lasting 6 h each the system capabilities can be summarized as follows :

- survey path	40 - 80 km
- photo pictures	8000 - 16000
- detailed exploration area	0.2 - 0.4 km2
- subbottom profile	40 - 80 km2
- sonograph covered area (side looking sonar)	12 - 24 km
- video pictures	24 h
- physic-chemical data	24 h
- mass of collected nodules	up to 200 kg

The same information collected using traditional means or one submersible only would require minimum double amount of operational time. Thus, a cost of the proposed dual AROV system development is very attractive if we consider potential operational savings. Moreover, reliability of the total system itself is increased while the cost of construction of the additional AROV unit is lower in comparison to a single AROV with greater endurance and payload.

Vehicle components

General arrangement of NODULE AROV is presented in Fig. 3. There are typical ROV components as: syntactic foams, manipulator, underwater photo camera with flash unit, TV cameras and electrical underwater connectors. Standard subsystems and other typical components could play a very important role in decreasing the total cost of the system construction. Another advantage of application standard components is cost saving during exploitation of the real system. Proved systems tend to bring less problems then prototypes.

Some subsystems should be developed or built using various adaptation techniques to upgrade available components and get the desired system performance. There are: energy supply system, motion system, artificial intelligence modules, control system and specialized hydroacoustic systems.

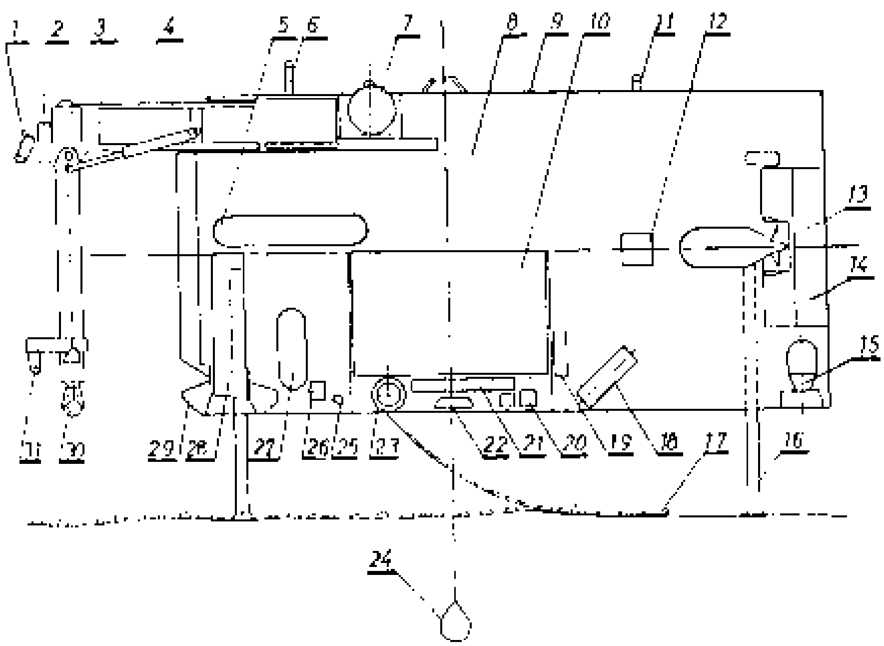


Fig.3 General arrangement of the NODULE Autonomus Remontely Operated Vehicule

Work Suite

The work system package of the NODULE AROV consists of:

- wireless, monochromatic, high sensitive TV system with hydroacoustic transmission link
- CCTV with VCR (on the board of AROV)
- photographic system (TV camera) and lighting system (flash, UW lights etc.)
- manipulator with revolving, barrel magazine for nodule samples
- subbottom profiler
- side scan looking sonar
- oceanographic equipment with recorders

The most suitable tool package is selected according to current requirements. Normal payload could be increased and as a consequence more nodule samples could be collected. Modification and improvement of basic parameters of the system could also be possible using more efficient batteries or low density syntactic foam blocks.

Wireless TV Observation System

A transmission TV pictures is the most crucial subsystem for assumed AROV control and operation. The NODULE communication operates using hydroacoustic link. TV pictures and control data could be transmitted over quite long distance up to 2000-3000 m. Suspended transmitting station which is lowered from mother support ship enables the reduction of the length and optimization of the hydroacoustic transmission path.

According to actual requirement TV picture could be degraded to a desired level according to the following degradation levels:

1. Full resolution TV picture (up to 500 TV lines)

2. Degraded TV picture showing the contour of the

elements laying on the bottom (modified full resolution TV picture)

3. Picture with contour of the nodules reduced to a symbol of selected nodule and the contour of the manipulator jaws and arm

for detailed investigation of selected location the NODULE is capable to land on the bottom. Three legs keep the vehicle in an appropriate distance over the seabed. TV or sonar picture transmission could be started to enable nodule site teleobservation. AROV pilot needs TV picture with at least 250 lines resolution renewed each 4-5 s for effective guidance.[3] However, this picture is not necessary for NODULE piloting. Forward looking sonar seems to be more useful for safe guidance of the vehicle. Obstacle avoidance sonar pictures are transmitted to the surface upon request. Side looking sonar images and subbottom

profile are stored in NODULE computer and could also be transmitted to the surface if required.

The TV picture analysis system allows the determination of size and coordinates of the nodules in reference to a manipulator coordinates. AROV operator or geologist selects the desired nodule sample. The geologist could have a rare opportunity for selection of nodule samples in almost real time. A video picture of the investigated place and photography is taken as well. Associated bottom characteristic and other site data are collected and stored in computer memory for detailed analysis on surface. All. the operations are performed automatically, controlled by' AROV processor. Manipulator jaws with selected nodule in it place the sample in the nodule store. Each sample is placed in separate container similar to gun barrel. At the same time appropriate ballast weight is released.

TV transmission is planned on 60 kHz frequency using FSK coding. Range of TV picture transmission could be possible for 1 -2 km. Telemetric data transmission and pilot commands is planned on 21 -28 kHz respectively for a distance up to 3 km.

It is assumed that in coming years commercial version of wireless hydroacoustic will be available on the market.

Control System

Basically NODULE AROV motions is controlled automatically. Highly specialized processor on board of AROV takes control over the vehicle using all the navigational and hydroacoustic sensors. Two-way communication with surface control unit is limited to the transmission of some commands and status information of the crucial AROV subsystems. This regards: manipulator, observation tools, motion subsystem and emergency conditions. One of the channels is totally used for emergency communication channel. It is obvious that NODULE AROV navigation is supported by reliable underwater navigation system. Data from AROV inertial navigation module are transmitted by telemetry channel and compared with data from LBL underwater navigation system.

Summary

This brief description of NODULE Dual AROV presents only the most important system features. Components for advanced AROV for mineral deposits investigation could be purchased or be developed using existing ROV technology. Critical problems are associated with reliable hydroacoustic transmission over long distances and artificial intelligence modules. Using today computer technology it seems quite sure to see similar AROV deepsea exploration system before the year 2000.

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