Thin Cable System for ROV and AUV in JAMSTEC

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***Abstract*- The ROVs with thin cable system have been developed in JAMSTEC. The thin cable system is very convenient for AUVs, therefore it has been applied for the AUVs that have been developed in JAMSTEC.**

Conventional ROV systems need the thick cable to supply electric power from mother ship to under-sea vehicle. In the thin cable system, a thick cable is not necessary because a power source like a battery is installed in the vehicle. The communication between the vehicle and mother ship just needs to include observation data from vehicle and control data from mother ship. And the data are communicated through only one optical fiber cable that is about 1mm in diameter. The thin cable system is called "UROV system" in JAMSTEC.

UROV system has some merits because of thin cable. The first, since the optical fiber cable with the length of 10km is installed in the small cylindrical case called "spooler", the onboard system is very compact against conventional ROVs. The second, if a tether cable gets entangled in something like under-sea structure, it is considered that a vehicle can not be recovered in worst case. But in that case, in UROV system, the vehicle can be recovered, because it has safety sequence that is to release the ballast for surfacing. And UROV system has other merits, for example, there is no cable drag.

UROV system is available not only ROV but also AUV. *URASHIMA* developed by JAMSTEC has 3 operation modes. UROV mode is one of these operation modes. Mainly this mode is useful for debugging in early stage of developing. When troubles happen, it is difficult for normally AUV that has no cable to know the detailed state on real-time. In that case, in *URASHIMA*, UROV mode is very convenient debugging of software and hardware. Furthermore, *URASHIMA* can survey like ROV by optical communication for UROV mode, for example, to watch the TV image on real-time.

This paper is described with UROV system for 7,000m class UROV, *UROV7K* (Fig.1), and AUV, *URASHIMA* (Fig.2).

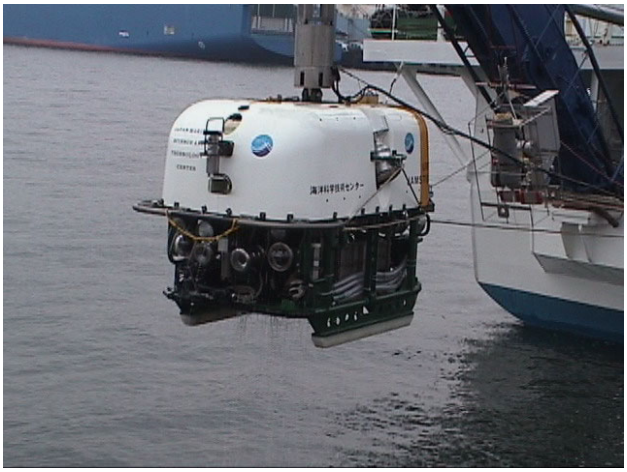


Fig.1. *UROV7K*

Fig.2. *URASHIMA*

I. INTRODUCTION

When conventional ROVs investigate deep-sea mooring systems and complicated sea-bed, there is some possibility for tether cable of them to get entangled in some obstacles or mooring cables. In worst case, tether cables are cut off by them. It is dangerous for manned submersible to investigate there. Thin cable system ROVs in JAMSTEC are developed to investigate above dangerous places.

In UROV system, a battery for power source is loaded on a vehicle, and there is only one optical fiber cable of 1mm in diameter between the mother ship and vehicle. The vehicle is controlled through the thin cable, and observation data included TV image is observed on the mother ship. If optical fiber cable is cut off by some obstacles or gotten entangled in mooring cables, the vehicle releases the ballast, then surfaces. It is possible not to recover ROVs, but they can recover in UROV system.

This system is available for AUVs. When troubles are occurred in sea trials in development stage, it is difficult to investigate the state of AUVs, which have no cable. Generally, after recovering, the logging data in AUV is investigated and tried to find the cause. However, using UROV system, which the state of AUV can be confirmed in real-time, it is useful for debugging of the control system and development period is shorted. Furthermore, it can be applied for the missions that the researcher want to observe in real-time onboard.

In JAMSTEC, UROV systems have been developed since 1990. *UROV2000* (Fig.3), which was a prototype of UROV system, and *GENTATSU500* (Fig.4), which was a practical use, were developed. Now *UROV7K*, which is the 7,000m class UROV system, has been developed. For AUVs, UROV system is used in *URASHIMA* and *MR-X1* (Fig.5). Otherwise, a borehole utilization system *BENKEI* (Fig.6) has this system.

There are many AUV and ROV systems using with UROV system in JAMSTEC (Table 1). This paper is described with the operation of UROV system about 7,000m class UROV, *UROV7K*, which cruising depth is No. 1 in UROV system, and AUV *URASHIMA*.

Table 1. UROV system in JAMSTEC

NAME	TYPE	YEAR	NOTE
UROV2000	UROV	1990	Prototype, 2000m class
GENTATSU500	UROV	1992	Practical use, 500m class
UROV7K	UROV	1998	Deep-sea type, 7000m class
URASHIMA	AUV	2000	Long cruising type(300km), 3500m class
MR-X1	AUV	2002	Marine robot, 4000m class
BENKEI	ROV	2001	Borehole utilization system, 6000mclass

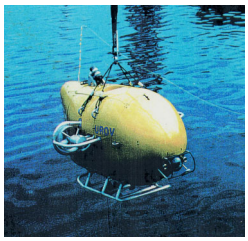


Fig.3. *UROV2000*

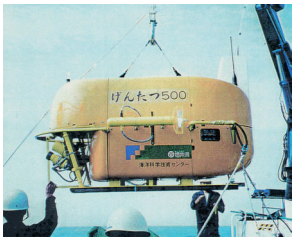


Fig.4. *GENTATSU500*

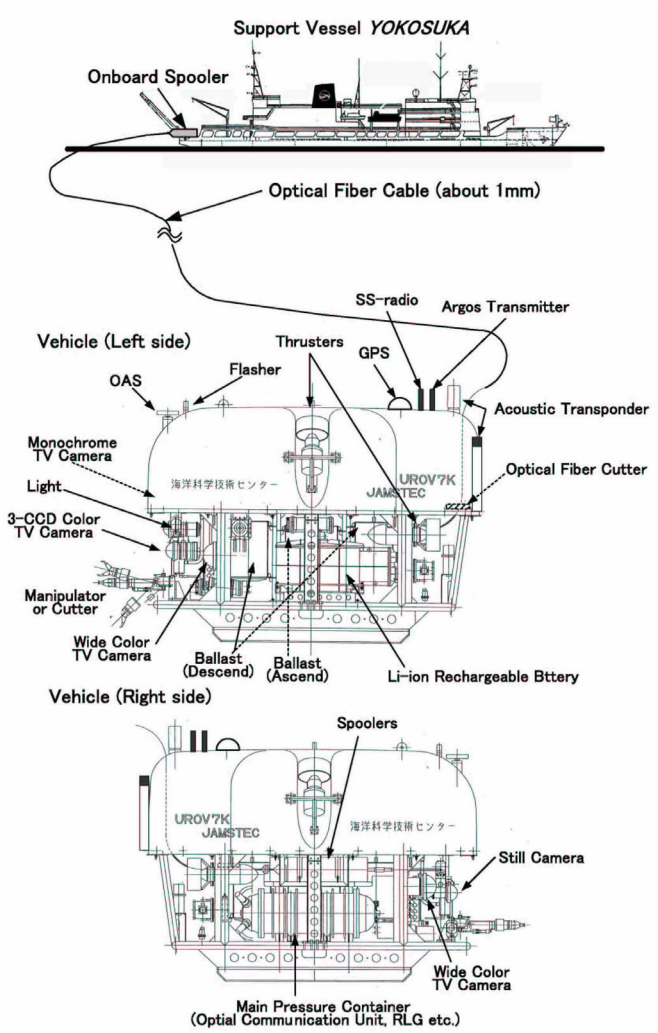
Fig.5. *MR-X1*

Fig.6. *BENKEI*

II. UROV SYSTEM AND APLICATIONS

A. General Operation

Fig. 7 is the specification of *UROV7K* system. *UROV7K* is composed of frames which are made of aluminum pipe enclosed oil, buoyancy materials, observation equipment, cruising equipment, thrusters, battery and ballast tank. And special equipment for UROV system is spoolers that are loaded on the vehicle and mother ship.



Weight	2,700kg
Dimension	2.8(L) x 1.8(W) x 2.0(H) m
Operating Depth	Max. 7,000m
Power Source	Lithium-ion Rechargeable Battery, 108V /60Ah
Propulsion	2 horizontal/ 2 vertical, DC brushless, 800W
Equipment	Wide color TV cameras(x2), Monochrome TV camera, 3-CCD color TV camera, Still camera Altitude sonar, Ring laser gyro, OAS, Depth meter, Acoustic transponder Etc.

Fig.7. *UROV7K* system

10,000m optical fiber cable is installed in this cylindrical case. Optical fiber cable is spooled out of a spooler by weak power of about 200g. The causes, which the optical fiber cable is spooled out of onboard spooler, are for surface tidal current and moving distance from mother ship. Therefore, *UROV7K* has two spoolers (total 20,000m optical fiber cable) like Fig. 8 to cruise to 7,000m depth. And for power source, oil-filled lithium-ion rechargeable battery is installed in *UROV7K*. Since it has high efficiency, it is used for cellular phones or automobiles.

The general operation of UROV system is shown in Fig. 9 (Ex. *UROV7K*). The vehicle is descending and ascending by weight of ballast without using thrusters to reduce power consumption. The descent ballast is released near sea-bed to be neutral buoyancy, then the vehicle cruises for observation using thrusters. Finishing observation cruising, the ascent ballast is released and the optical fiber cable is cut off to reduce the consumption of optical fiber cable. After that, the vehicle is surfacing without thin cable.

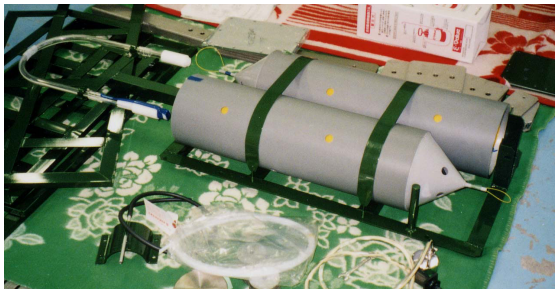


Fig.8. Spoolers for vehicle in *UROV7K*

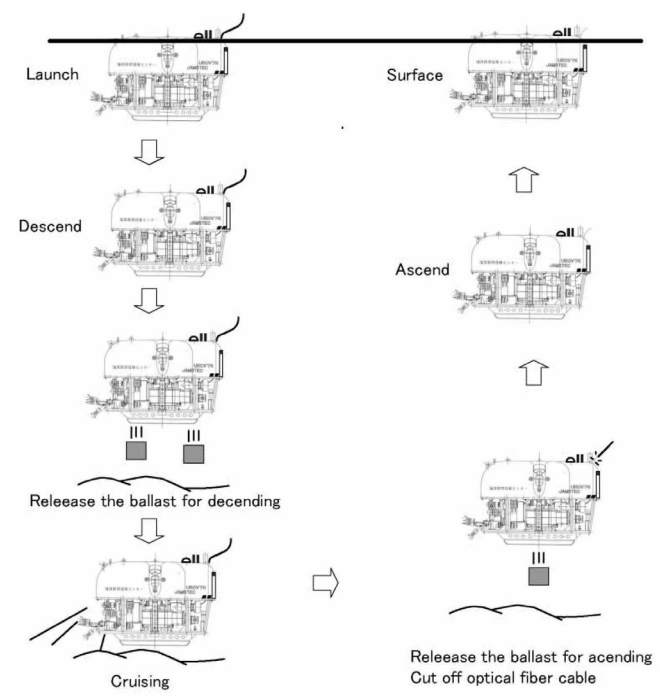


Fig.9. General Operation of *UROV7K*

It is considered not to recover the vehicle in worst case if some troubles occur in the tether cable, because not to cut off tether cable is a requirement for conventional ROVs. On the other hand, in UROV system, the vehicle has the emergency action releasing all ballast when optical level is reducing by some troubles. Therefore the vehicle can be recovered if the optical fiber cable cut off. Furthermore if the vehicle surfaces far point from the mother ship, the position of the vehicle can be confirmed by SS radio included GPS data and argos transmitter.

B. Deep Sea Operation

Optical fiber cable is spooled out by weak power (about 200g) like surface tidal current, wave, and wind. If the optical fiber cable spooled out of spooler is needlessly long, it is possible to get entangled and cut off. Especially, over 3,000m depth area, decent time is long and needless part is long. Therefore, to short needless part is very important point in UROV system.

There is a winch to measure of that in *UROV7K* system. The winch can descend onboard spooler until 500m depth (Fig 10, 11, 12). After the vehicle into the sea, the onboard spooler is descending into the sea to protect the effect of tidal current, wave and wind.

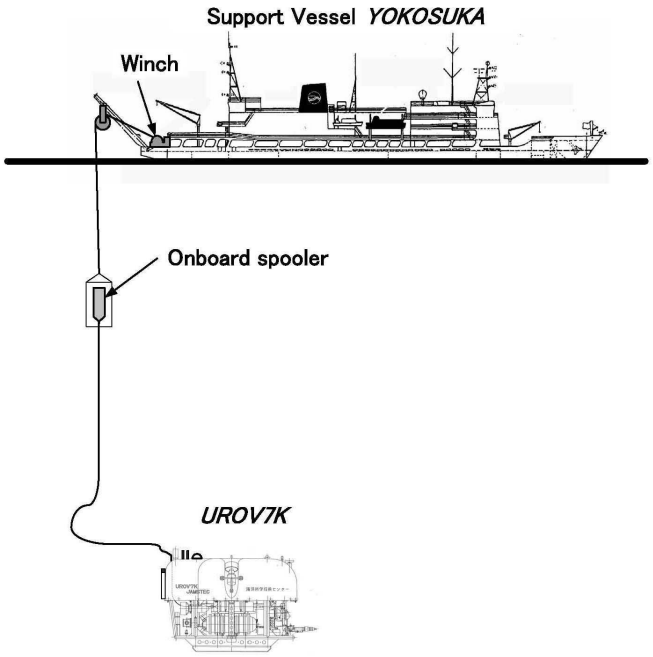


Fig.10. Deep-sea Operation (using winch)

Fig.11. Winch for onboard spooler

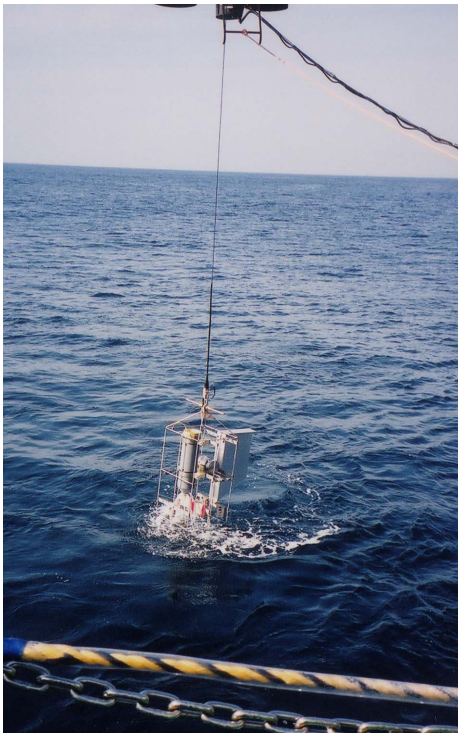


Fig.12. Onboard spooler mounted on the frame for descent

C. AUV Operation

Usually AUVs cruise without cable in test. If some troubles occur in cruising, the causes of troubles are investigated by logging data in AUVs after recovering. UROV system is used in *URASHIMA* loaded on a complicated fuel cell system to watch the state of the AUV in real-time. The state of hardware and software in the AUV can be always watched by UROV system. The states of troubles are easily confirmed and countermeasures are quickly taken. That is useful to shorten the development period. Furthermore, in limited area, it is possible for *URASHIMA* to do real-time observation that can not do it for conventional AUVs.


Fig.13. Onboard spoolers for *URASHIMA*

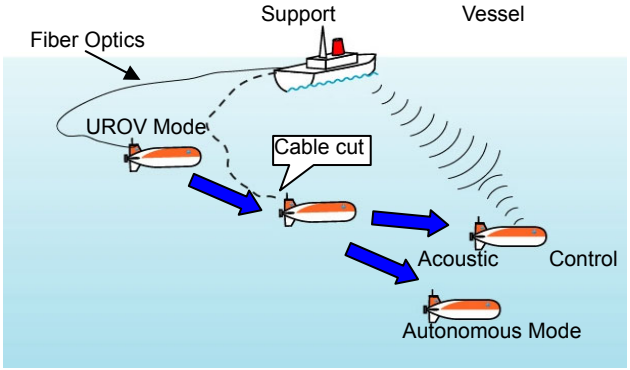


Fig.14. UROV mode operation for *URASHIMA*

The mother ship and the AUV are always moving since the mother ship is always near the AUV in cruising in UROV mode. Therefore, it is impossible to use the winch in AUV operation like *UROV7K*. However, optical fiber cable is kept to stretch since the mother ship and AUV are always moving. The winch system is unnecessary for AUV. Onboard spoolers are connected tandem like Fig. 13 since the cruising distance from the mother ship is very long.

Always, *URASHIMA* cruises in UROV mode until 500-1000m depth after launching to confirm the state of all equipment. Then it moves to acoustic control mode or autonomous cruising mode. This is useful for improvement of reliability in long cruising. (Fig.14)

III. OPTICAL COMMUNICATION SYSTEM

Fig. 15 is the optical communication system for *UROV7K*. Interactive communication is carried out and single mode optical fiber is used. Uplink wave length is 1300nm and downlink wave length is 1550nm. The capacity of uplink, which includes 3 TV channels, is about 600Mbps. The capacity of downlink, which includes only vehicle control lines, is about 30Mbps. Since an alternative switch is installed in 3 TV channels, it is possible to install maximum 6 TV cameras. The optical power level is always watched, and if it keeps lower level for several seconds, the vehicle moves

to the emergency sequence, which is to release the all ballast and ascend.

Downlink wave length (1550nm) has good straight characteristic but it is weak for bending compared with uplink (1300nm). Therefore the optical amplifier is installed in downlink line of onboard optical communication system to be the same optical power level of uplink and downlink.

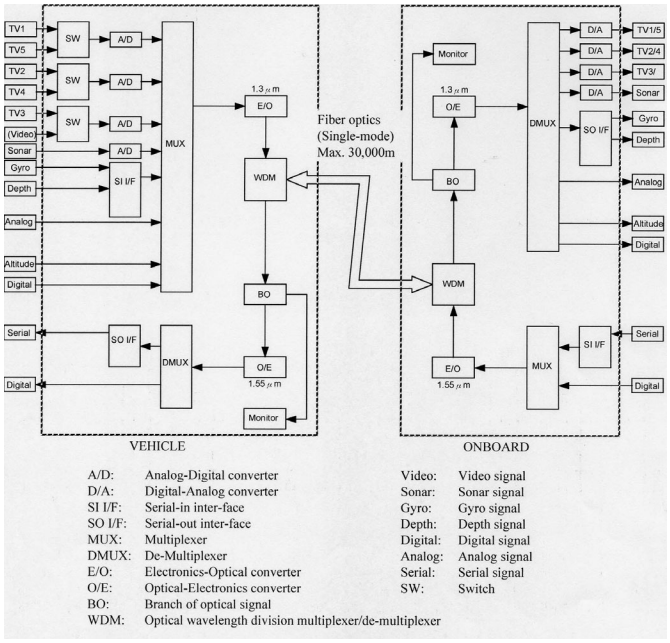


Fig.15. Optical communication system for *UROV7K*

IV. SEA TRIALS

A. UROV7K

The sea trials of *UROV7K* were carried out about 10 dives in 4 cruises until now. UROV7K dived to 3,700m depth, which is the new record of UROV system, on March, 2003. Onboard spooler was going down into the sea after launching the vehicle. The vehicle was descending slowly at the speed of about 44 m/minute. Optical power level is the stability and beautiful TV image of the seabed at 3,700m depth could be observed (Fig.16).

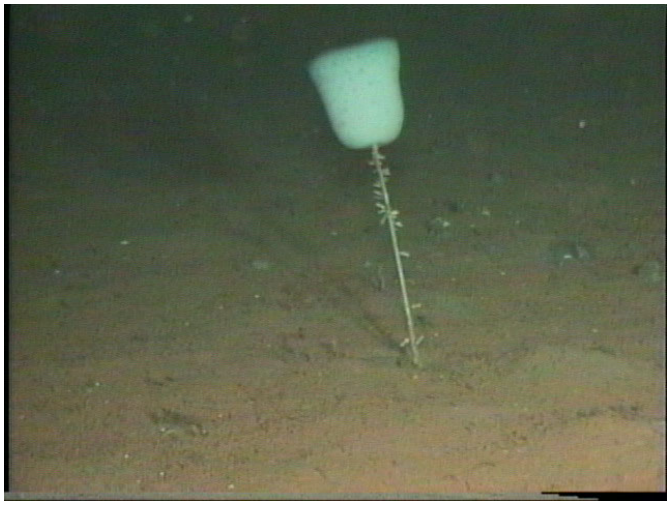


Fig.16. The TV image of 3,700m by *UROV7K*

B. URASHIMA

The sea trial of *URASHIMA*, which was cruising to maximum operation depth, was carried out in UROV mode on August 2001, and reached to the seabed of 3,518m depth. *URASHIMA* descended tracking the spiral to the depth of 3,518m like Fig. 17 Its cruising distance was for about 7,000m, which is the same as the consumption of optical fiber cable in *URASHIMA*. There are no problem in this test. Fig. 18 is the TV image of the sea trial for maximum operation depth.

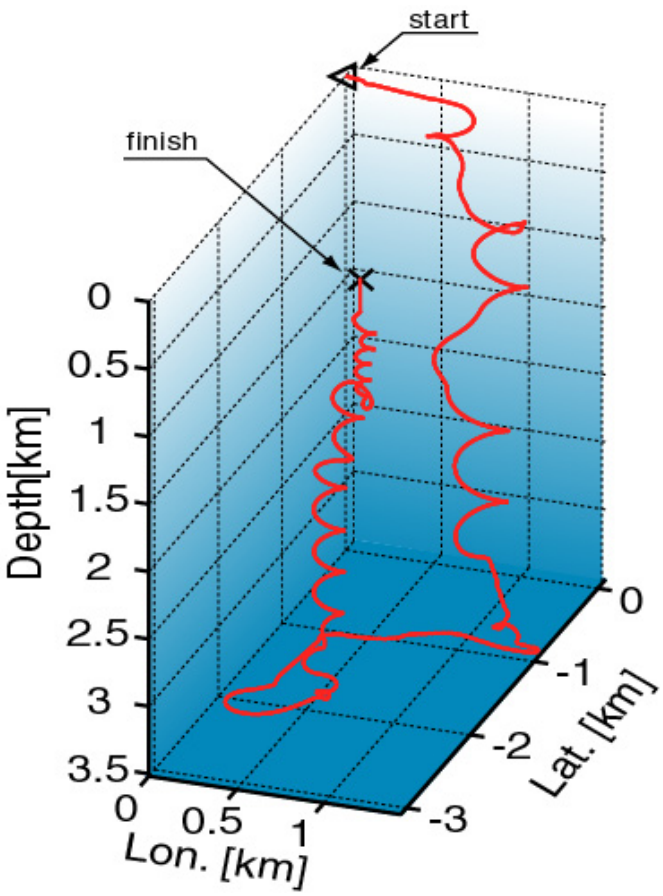


Fig.17. The track of *URASHIMA* for max. operation depth trial

Fig.18. TV image of 3,518m by *URASHIMA*

V. CONCLUSIONS

UROV system has been tested about 4,000m depth area. If we are careful of the tension of optical fiber cable, it is considered that the test of 7,000m depth will be succeeded. It has been confirmed that the UROV system is useful for AUV in *URASHIMA*. Therefore UROV system is used other AUV and ROV systems in JAMSTEC.

In the future, this system will be extended other systems. For example, Fig.19 is the new AUV-UROV high-bride type vehicle for shallow water. This vehicle is developing by collaboration with KOWA Corporation. A few years later, it will be on sale.

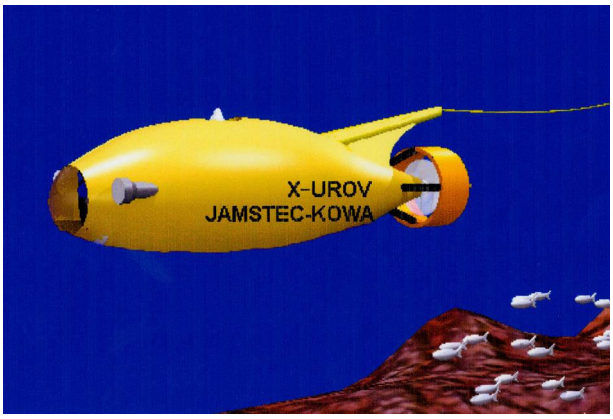


Fig.19. New high-bride type AUV for shallow water

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