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AUTONOMOUS UNDERWATER VEHICLES - A DATA COLLECTION TOOL FOR AMBIENT NOISE MEASUREMENT IN AN ARCTIC ENVIRONMENT

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1 INTRODUCTION

This paper addresses the use of Autonomous Underwater Vehicles (AUVs) as a tool for acoustic noise measurement underwater. A description of the key elements of a generic AUV is provided along with an overview as to likely vehicular performances. Several noise measurement tasks are identified and mission plans are discussed. The paper then proceeds to discuss the implications of the noise assessment installation to AUV design and concludes by presenting a suggested solution to the task of designing a noise measurement AUV.

The starting point to enable us to consider the application of an AUV for acoustic tasks must be an easily understandable and recognisable definition of what is meant by an AUV. Many definitions exist and all tend to differ in terms of what is meant by "Autonomy". For the purposes of this paper we shall define a generic AUV as being a vehicle with

- an onboard energy source
- a navigation facility based upon vehicle mounted sensors.
- a sensor system (payload)
- a data recording facility
- an executive processor controlling the AUVs run plan

This is shown schematically in Figure 1.

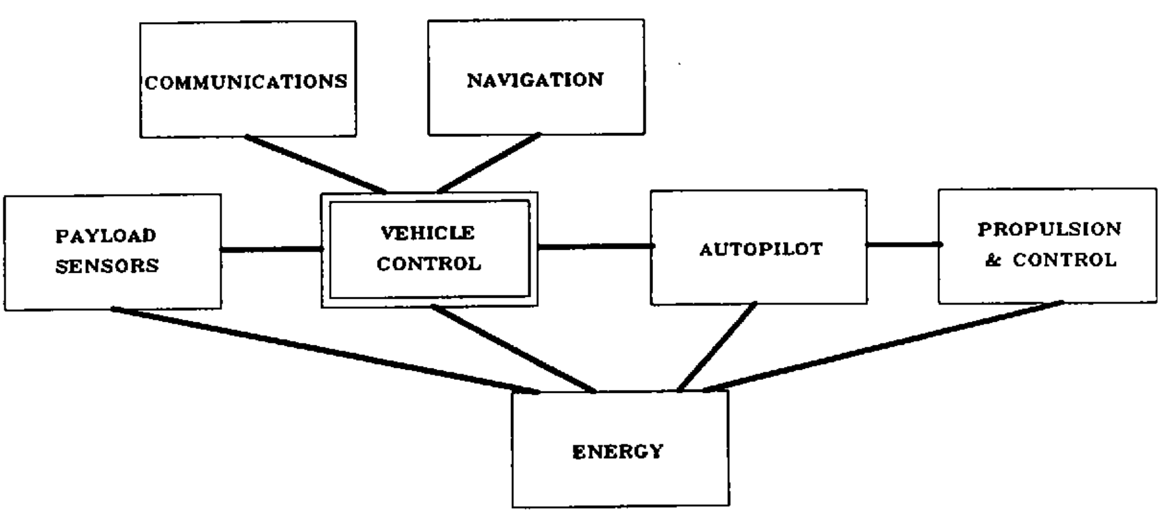

Figure 1 AUV SYSTEM BLOCK DIAGRAM

Figure 1 shows in block diagram form these key elements arranged to form a basic AUV. The most important systems interactions are shown, but it must be noted that any real AUV will be a considerably more complex device. The block diagram shown could therefore be applied to an AUV of almost any size. However, if it is to be used as a scientific tool, then practical constraints need to be applied. The first and most obvious is that the AUV must be tailored to the requirements of the scientific mission. To provide a discussion point, let us assume that the main requirements are for an AUV to operate at shallow depth over a range of say 500 km and with an endurance of say 48 hours. It may also be important for the AUV to be easily deployed from a research vessel. This applies size constraints and mass limitations. Trade off studies on these basic parameters start to provide practical limits and constraints for a data gathering tool. To achieve the range and endurance, power consumption must be low. This implies low speed, say 5 knots (2.5 m/s) velocity of the AUV through the water, and also implies a low power consumption payload. The AUV will look somewhat like the traditional military torpedo shape, although its characteristics and performance would be considerably different.

The sensor fit of the AUV will be very much dependent upon the mission. Many Oceanographic missions can be envisaged for AUVs. Long term, AUVs are likely to become widely used as a means of multiplying the effectiveness of survey vessels and as a means of achieving cost savings.

2 AUV MISSIONS

In the short term, however, AUVs are only likely to be used for tasks that cannot easily be accomplished by other means. One of the most obvious of these is Polar Research. Under ice surveys using sonar techniques are possible using AUVs and these survey missions can be extended to include Acoustic research. Provided that the AUV is not generating noise sufficient to disturb the data, ambient noise measurement under the ice can be made a practical reality. Figure 2, below, shows a possible scenario for such a mission.

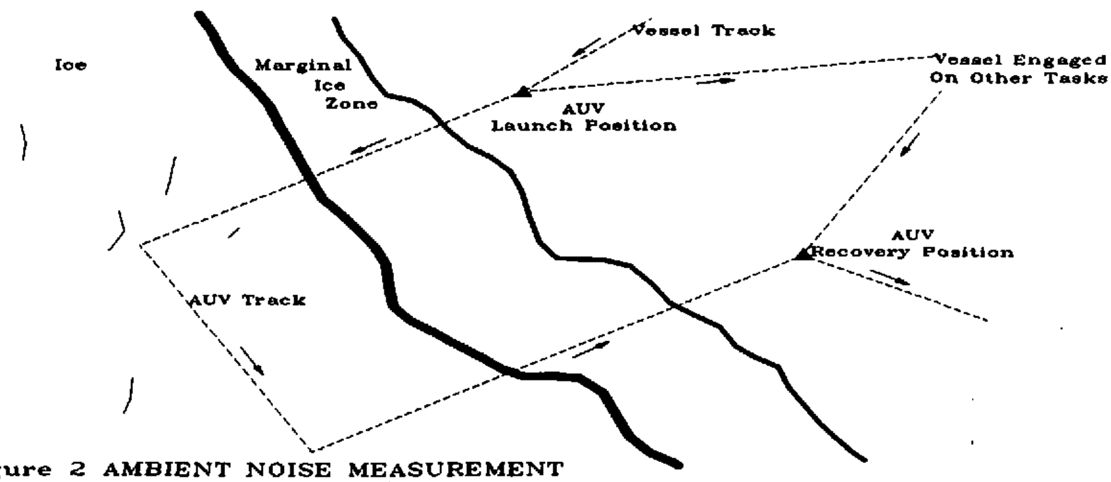

Figure 2 AMBIENT NOISE MEASUREMENT MISSION

A survey vessel can deploy the AUV clear of the ice, then withdraw to carry out other scientific missions. Total track lengths of several hundred kilometres will be achievable within the foreseeable future with missions lasting up to 48 hours. The type of mission proposed in this paper allows for scientific measurement to be made in a range of conditions ranging from open water, through the marginal ice zone, into complete ice cover. Such a mission could combine oceanographic measurement with noise measurement. Figure 3 shows the simplest of missions that might be run.

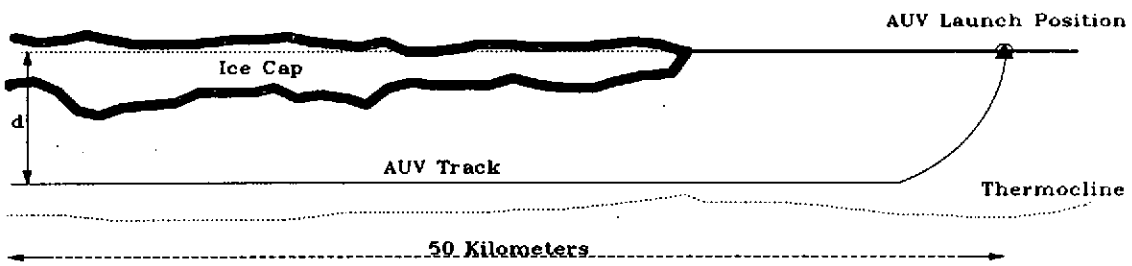

Figure 3 AUV MISSION – DEPTH PROFILE

In this scenario the AUV would be run at a constant depth (d in the figure) preprogrammed prior to launch.

Figure 4 shows a more complex possibility for the AUV mission.

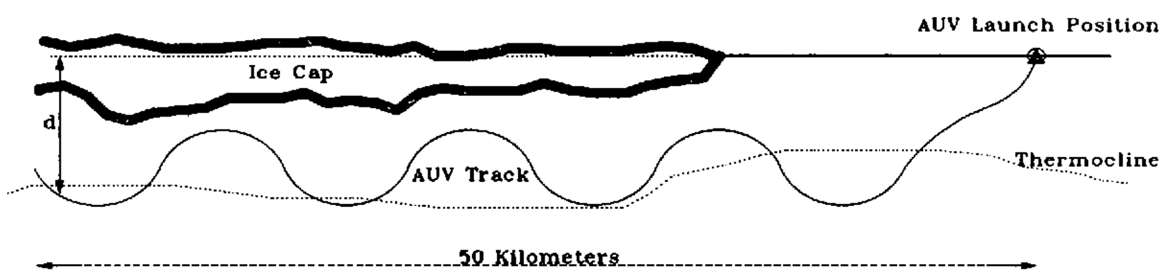

Figure 4 AUV MISSION – UNDULATING DEPTH PROFILE

In this case the AUV would undulate over a depth range of several hundred metres, emulating the Chelsea Instruments Seasoar. However, as more payload volume is available than in the Seasoar, and there is no link to a surface vessel, the under ice missions become practical. Missions of this type are well within the capability of existing and near term AUV technology.

3 THE SENSOR FIT

For the simple ambient noise missions the AUV will need to be equipped with the following systems

- Oceanographic suite
- Acoustic sensors
- Data logging suite

In all probability the AUV would also be able to carry survey sonars. However these would not be run concurrently with the acoustic sensors.

The oceanographic suite would as a minimum consist of Conductivity, Temperature and Depth (CTD) but more probably include additional mission specific sensors.

The acoustic sensors fitted will be dependent on the specific acoustic requirements for the mission. The mission illustrated in Figure 2, designed for ambient noise measurements, would require a broadband passive sonar system which would cover a frequency range of say 10 Hz to 20 kHz. The system would not need to be particularly complex in this case as no directivity information is required. Noise measurements can be made either continuously throughout the mission or at specific points in the mission. For example there may be no requirement to start measuring until the AUV is under the ice. Various data logging options are open and will be discussed later in this paper.

An alternative mission for the AUV is shown in Figure 5.

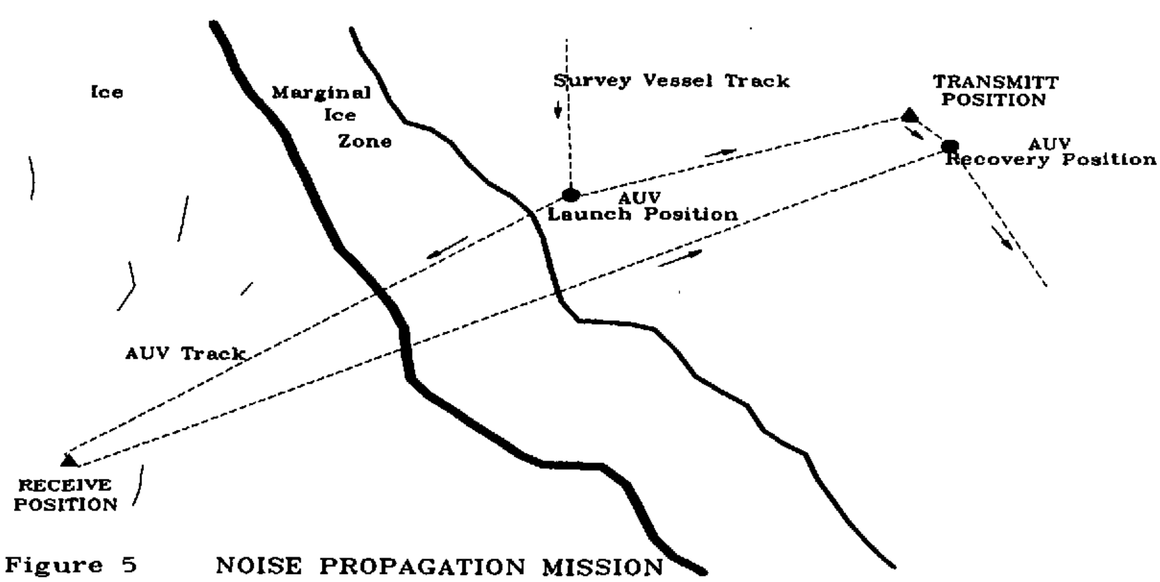

Figure 5 NOISE PROPAGATION MISSION

This mission addresses noise propagation. The figure shows a scenario where the transmitting vessel and the receiving station might be several hundred kilometres apart. To make such a mission practical the AUV would in practice be the receiver and run plans would be structured to provide a variety of possible transmission paths, with the AUV located at several scientific stations covering a range of depths. The sensor fit of the AUV will need to be somewhat different from the previous mission. The specific details of the sensor fit depend on how the trial will be carried out. At the long range suggested, the frequencies of interest will necessarily be low, say less than 100 Hz. The noise sources may be impulsive or continuous so the processing on the AUV will need to be optimised. In addition, in the case of the impulsive source, the AUV will receive the pulse several minutes after it was transmitted. This will necessitate some form of communication between the support vessel and the AUV to ensure that recording systems are not in use unnecessarily for long periods of time. For example pulse doublets could be used, one to power up the system and one to measure. Sensors will be required to enable correlation of propagation and depth of receiver.

The embodiment of the above sensor fits into the AUV will influence the AUV design.

The objective of the acoustic design of the AUV is to ensure that the sensors are not affected by vehicle generated or electrical noise, ie self noise levels are low. The proposed operating speeds for these acoustic missions is low at about 2.5 m/s so flow noise levels will be minimal providing care is taken to ensure that any excrescences are designed with care, for example sharp corners are avoided.

The key to a successful low noise design is to ensure that the acoustic design is considered from the outset. All design authorities, must be involved. This includes for example propulsion, hydrodynamics, structural and payload systems. Cooperation at this stage will ensure that the self noise requirement for the acoustic sensor fit is consistent with the vehicle hardware. Areas for consideration during the acoustic design would include soft mounting the propulsion system, flexible drive shaft couplings and hull damping materials. It can be seen from Figure 6 that the propulsion system is at the rear of the vehicle away from the sensors. Vibration transmission down the vehicle will be reduced due to the joints between the sections. Sensors such as a side-scan sonar may present some difficulties being in intimate contact with a considerable length of hull but the use of vibration damping and isolation materials in these areas should alleviate any problems.

4 A PRACTICAL SOLUTION TO THE PROBLEM

The practical realisation of these features could be the AUV shown in schematic form in Figure 6.

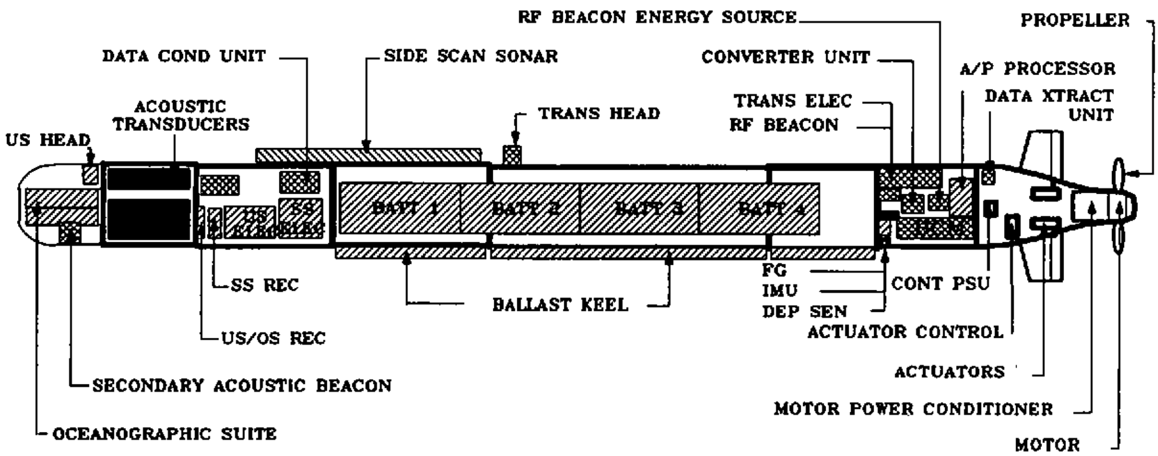

Figure 6 AMBIENT NOISE MEASUREMENT AUV

This vehicle is based around torpedo sized components, has a length of just over six metres and has a mass of approximately 1.3 tonnes. Such a vehicle is thus sufficiently small to be deployable from the majority of the science community's research vessels.

The key performance parameters are likely to be :-

speed	-	2.5 m/s
range	-	400 km
endurance	-	48 hours
energy storage	-	40 kW hrs
data recording Capacity	-	2.5 G Bytes
Sensors	-	Sonar 100 kHz
		500 kHz
	-	CTD
	-	Water Chemistry
	-	Noise measurement
Navigation	-	heading accuracy 1°
Communications	-	via satellite once at surface

The recording system on-board the AUV will need to be able to store data in a form to facilitate subsequent analysis. It is proposed to digitise the data and store data in digital form. However at very high frequencies the digitisation rate may preclude raw data storage thus necessitating some on-board processing.

This AUV will be capable of operating for extended missions over timeframes of several days. By suitable choice of subsystems and careful engineering design quick turnaround of the AUV in an operational environment can be achieved. Currently envisaged turnaround times are in the order of 12 hours with no necessity to access the inside of the vehicle. Data retrieval is planned to be achievable in three hours.

It is easy in a paper such as this to put forward technical solutions to problems. This vehicle will have to be operated in adverse climatic conditions and in high sea states. Consideration has thus been given to the operational reality of working at sea and deploying, and perhaps more importantly, recovering underwater vehicles.

This paper proposes that an AUV is a viable tool for Ambient Noise measurement in the Arctic. Several mission profiles have been suggested, although it is acknowledged that the range of applications will only fully develop as AUVs become more widely available and accepted. The sensor fit proposed is one of many possibilities and it should be noted that the vehicle itself is only the first step towards future generations of such underwater vehicles.