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AUTONOMOUS UNDERWATER VEHICLES - EXTENDING THE SENSOR HORIZON

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1. INTRODUCTION

Remotely operated vehicles (ROVs) have been used operationally for many years as platforms to carry sensors away from ships. However, they suffer from the disadvantage of requiring continuous human operator supervision and they are generally constrained by the need for a heavy umbilical. In contrast, Autonomous Underwater Vehicles (AUVs) require minimal human operator intervention and will be free of constraining umbilicals. This means that they could provide platforms to deploy sensors independent of and far removed from a parent ship. In short, AUV mounted sensors can view remote horizons.

The Admiralty Research Establishment recently initiated broad based studies of a range of potential uses for such AUVs, examining the technological implications of their development. The aim of this paper is to delineate briefly the status of the necessary enabling technologies needed to implement an AUV platform, and to point to the potential advantages of pursuing the research and development associated with those technologies on a collaborative basis, involving both Industry and Government.

2. CHOICE OF SCENARIOS

2.1 When thinking, with a relatively unconstrained view, about the possible uses of AUVs it is easy to generate a list of many tens of situations where an AUV could be of great use. These range from the simple to the complex and cover a wide range of tasks. For our studies this initial list was reduced to 30 specific scenarios which received detailed consideration. The intention in making the selection was to cover as many different types of vehicle as possible while generating specific parametric information in each case. To achieve this the vehicle requirements ranged from little more than the automating of ROV technology to very advanced, fully autonomous vehicles capable of long duration deployments. In order to fully exploit the potential capability and advantages of AUVs priority was given to scenarios which complemented rather than replaced the capabilities of manned vessels.

In the studies each of the 30 task scenarios was precisely defined and treated in isolation to ensure that specific material conclusions were drawn in each case. Each task was considered in two stages: firstly, the characteristics and performance required by the vehicle to meet the objective were defined; secondly, these requirements were assessed in terms of their engineering practicality. In this way the feasibility of fulfilling the requirements of each task using an AUV could be judged. For each of the 30 scenarios a core data set of AUV characteristics was produced; this covered such features as speed, endurance, communications and navigation. The next two sections of the paper will highlight the main trends in this data set of characteristics and those areas of technology which emerged as being of most importance or most generally useful.

3. KEY AUV CHARACTERISTICS

3.1 Expendable versus recoverable vehicles

The first and probably most important conclusion that can be drawn is that AUVs, in whatever shape or form, will not be cheap. In many cases the scientific data gathering AUV will be engineered to have a life of many missions over several years, the question of expendability does not arise. In some cases, however, the use of an expendable vehicle could be appropriate. Here the cost could be cut by reducing the level of engineering to a "one use only" level but on deployment the decision is then taken to consume a significant resource. A recoverable vehicle, while having a greater initial cost, would work out much cheaper on a "cost per task" basis. There would, however, be the not insignificant cost and complexity of equipping the mother ship with a reliable recovery system.

3.2 Speed and Endurance

In many cases, such as large scale surveying tasks, the requirement is likely to be for a slow speed, long range vehicle with an endurance of a week or more. Typically, a speed of about 5 knots will be used to achieve the most energy efficient task profile. On some occasions, however, once a vehicle is launched it will be required to travel to and from its operating area at speeds of up to perhaps 20 knots. While on task a lower speed, say 5 to 10 knots, would probably be used to conserve energy. Often tasks will be conducted quite efficiently at a single speed, requiring only a simple motor system. However, in some tasks speed flexibility will be vital, allowing the vehicle to act in a reactive way to events happening close-by.

4. KEY AUV TECHNOLOGIES

4.1 Energy Sources

In the shorter term at least, the energy source considered to be the most appropriate in AUVs is the battery, either as primary cells for an expendable vehicle or as secondary cells for a recoverable vehicle. The reasons for this choice are that modern battery technology is well developed and offers good performance at low technical risk. Many suitable battery types already exist and emerging lithium based primary and secondary technology and sodium sulphur secondary technology are expected to offer some excellent characteristics. The simpler, but not necessarily the most energetic systems, offer the prospect of low risk solutions which should meet a majority of the likely requirements.
Among other possible energy sources, many forms of liquid fuelled thermal engines are available or are being developed. While these could find application in some AUVs they are, in general, more complex than battery systems. In the somewhat longer term, fuel cells hold great promise. The basic technology is well suited to the needs of the highly autonomous vehicles which will be needed for the long endurance tasks.

4.2 Communications and data processing

There are three candidate communications techniques available for AUVs: acoustic, fibre optic cable and radio. Acoustic links are most likely to be used to provide a short range backup capability since they will not have the range or data bandwidth to meet many requirements. They could, however, be invaluable during the launch and recovery phases of a task. For their primary communications system most AUVs will use either a fibre optic cable or radio link, with the choice between these being clear cut in many situations. Fibre optic links will provide a very wide bandwidth data transfer capability, allowing raw sensor data to be sent in almost all cases. They will, however, be expensive to implement and pose a major cable management problem. Radio, on the other hand, offers a relatively inexpensive and flexible capability but it has restricted data bandwidth and also requires the vehicle to approach the sea surface.
Given that most AUVs will be working at a significant distance from their base platforms, any fibre optic cable will need to use single mode technology. The cable will not be an umbilical in the ROV sense but will rather be a notionally tensionless cable which is deployed and left in the water. The potential problems associated with such a system are manifold. The AUV may have to carry many tens of kilometres of cable for use during its task. This implies that only minimal protection and strengthening of the fibre optic will be possible if unacceptable weight and space penalties are not to be incurred. The cables will therefore be somewhat fragile and cable management will become a major consideration. Once dispensed the

cable will lie in the water and will thus be vulnerable to being run down and cut by the AUV itself or its parent ship. Should ocean currents be affecting the area, the cable could be pulled into bunches; if a loop is pulled this could seriously attenuate or even block the light signal without the cable being physically broken. However, despite the risks, the high data bandwidth available with a fibre optic link would allow the transfer of raw video or sonar data directly from the AUV to the parent ship in real time and without any preprocessing, truly extending the sensor range.

The alternative to a physical cable link is a radio link, allowing the AUV a much greater degree of autonomy. However, a price does have to be paid for this freedom. Firstly, the AUV would have to either have to surface or come very close to the surface towing a surfaced aerial; in some cases this might not be possible. Secondly, the range over which data is to be passed will determine the frequency, and hence bandwidth, of the radio system. Possible systems could operate at frequencies from MF to UHF. Whichever technique is used, the data bandwidth will not allow the transfer of raw data in many cases. This leads to the need to employ data compression and data processing techniques onboard the AUV, the specific solution employed will depend on the particular task requirements.

4.3 Vehicle control and task management

Every AUV will have a basic computer based system to perform the control and management functions needed for autonomous action. This autonomy might endure only for a few minutes before an external command is received; conversely, the AUV might have to "survive" alone for several days. In either case the basic control architecture is likely to be the same. In particular, hierarchical and hetrogeneous structures can be envisaged with monitors or controllers of specific functions reporting to a supervisory system, perhaps with several independent sub-sections using a "majority vote" concept to reduce errors in decision making.

Among the important monitoring functions will be energy management and general fault location and identification. Among the sub-systems which will have to be controlled are the vehicle's autopilot and navigation elements. The autopilot will receive of a number of sensor inputs, such as attitude, speed and heading, and will then control the vehicle's motion in accordance with the task plan. Navigation might have to be achieved using internal sensors only, in a completely self contained internal system, or it could make use of external aids such as LORAN-C or GPS SATNAV, but to make use of these aids the vehicle would have to approach the sea surface.

The specific requirement for and the implementation of the navigation system is likely to be the most task dependent aspect of the vehicle control system.

4.4 Other factors

A very important factor in the design of the total AUV system will be the need to ensure third party safety. Good design will ensure that the vehicles are inherently safe for the operator but the presence of the many other users of the seas must be recognised. For example, tasks conducted in the coastal waters of the British Isles are bound to be influenced by the high densities of small fishing and pleasure craft, especially in the summer months. An AUV operating in such an environment must not only complete its task but also avoid the other traffic. If a fault develops the vehicle must fail safe, primarily by not coming closer to the surface than a preset depth without first receiving a "surface clear" message from either its own sensors or its parent vessel.

5. THE WAY AHEAD

It is clear that all AUVs will rely on a common base of sub-system technologies, although the relative emphasis and importance that is placed on each of these technologies will vary with the specific task objectives. All actual AUV system specifications will, however, have certain common requirements; an obvious example is the need for a navigation sub-system. It is therefore appropriate, at a time when AUVs are still in their childhood (their infancy being represented by a semi-autonomous one off prototype vehicles that have emerged during the past few decades) and when the relevant skill and material resources are under constant pressure, to look to collaboration to pursue the necessary R & D. Three advantages of such collaboration would be that:

5.1 at the outset an appreciation of the problems involved in sub-system integration would be established, ideally leading to some standardization of interface requirements,

5.2 specialist researchers and manufacturers could advance their own fields in the knowledge that their own sub-system elements will be of value in more than one (possibly a great many) vehicle applications, thus lessening the risk to their own programmes should any one AUV application fall out of favour,

5.3 resources could be deployed to best effect to support a single AUV programme rather than being spread thinly amongst a number of such programmes, none of which is likely either to attract or maintain the level of resourcing needed to sustain itself during this present stage in AUV evolution. The potential disadvantages of a collaborative programme (apart from purely bureaucratic obstacles) centre on the need to protect legitimate self interests. However, this need not be a problem if a clear distinction is drawn between the activities associated with overall vehicle system design and integration and those associated with sub-system design. For example, sensitive commercial interests could be fairly readily safeguarded because, to a large extent, sub-systems would be defined by their interfaces; the detail design need not enter the "public" domain. Likewise, sensitivities that relate to the overall configuration of a vehicle and the use to which it will be put could, be safeguarded where necessary provided "standard" sub-system interfaces are adhered to.

6. CONCLUSION

Despite a history spanning three decades, the true potential for AUVs is only now being recognised and realised, due in part to the maturing of the relevant enabling technologies and in part by the pressing need to explore the ocean by deploying sensors more widely. There are still technology risk areas that must be explored and understood but these are common to all AUVs. Collaborative programmes, wherein available resources are used in a complementary rather than competing manner, could offer significant advantages to sub-system manufacturers, vehicle designers and users of AUVs.