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MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Defence Applications of Marine Technology [and Discussion]

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Defence applications of marine technology

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The time it takes from the development of new technology to the introduction of operational systems in naval defence is generally approximately two decades; thus most of what will be applied in the 1990s is already in development. Some of the key areas of defence interests that are directly affected by advances in maritime technology are undersea detection (by sonar), atmospheric detection of flying objects, and ocean forecasting to the fleet. Developments in remote sensing, oceanic and atmospheric phenomena and very large computers and data banks are important in both deployment and operational strategies as well as the development of new systems.

Some of the major oceanographic and geophysical advances in this century were made because of the availability of defence technology. Examples are expendable temperature probes, sonobuoys for seismic refraction, and fathometry. It is interesting to examine what is being developed for defence purposes that may affect ocean research.

Introduction

The role of oceanography and ocean technology in the development of defence systems has been the subject of discussion, in most nations of which I am aware, for many years. When military budgets are curtailed and the cost of ocean research increases it is particularly important to be aware of the importance of oceanography and its related technologies. The questions that arise are: How much oceanography does the military need and how much of it can be reliably utilized from the private sector? The points of view are diverse, being spanned by the point of view of the research oceanographer on the one hand to the naval operator who is faced with reduction in operations, training and facilities on the other. I welcome this opportunity to address a few of my views on the subject. It will be appreciated, I assume, that the discussion can only be general, because specifics generally relate to systems or limits that verge on classified topics.

Military defence at sea requires the development of ships, systems and men to carry out marine operations that will protect maritime resources and territory, and, if necessary, project a nation's power to other areas of land and sea. Military ships must therefore be capable of their self-protection and be able to search and destroy other forces. Thus it is essential that the platform and its sensors and weapons be designed and constructed to operate effectively in the marine environment, that men be trained to use their equipment intelligently in the environment and that high-quality information on the environmental parameters affecting operations be provided in a timely manner and in an acceptable format.

From the initial development of a system concept to its final introduction to the fleet it is a difficult and sometimes nearly impossible task to have the environmental information available for development and training. Too often systems planners neglect or are unaware of the essential features of the sea and the developments in ocean technology.

Since I am to discuss the application of ocean technology to defence in the 1990s it is important to recognize that the development of major fleet systems is a very slow process indeed. The acquisition of defence systems in most nations takes between 10 and 20 years from concept to introduction. Therefore what is now in the pipeline of development will reach the fleets in the 1990s. Much, therefore, of ocean technological development that is or will be incorporated is already with us.

Even if systems acquisition has essentially frozen the incorporation of today's technology into current development there are important ways by which developing ocean technology and oceanography will have impact on the fleets of the 1990s. These are: data acquisition that is necessary for the intelligent operation of systems, and for forecasting estimates of systems performance in various areas and climates of the world, instrumentation to acquire pertinent data, and finally the numerical prediction of the oceans.

The effects of the sea on military systems can be grouped as (1) the hydrodynamic influences on platforms and systems, such as wind, sea and currents; (2) the ocean's variability and boundary effects on sensors, such as sound and electromagnetic propagation. Some major advances in ocean measurements, including remote sensing, marine geology and oceanography will therefore have an influence on operations. Also, if these prove effective, the development of military sensing systems will influence oceanography in the future in a pattern that has been seen in the past.

Ocean sensing

The developments in sensing the sea can be divided into remote methods, such as satellite or aircraft sensors, primarily electromagnetic, and most recently underwater acoustics and *in situ* devices, such as surface and subsurface buoys, both fixed and moving.

The first of these has been the subject of numerous meetings. The use of colour photography, infrared and microwave sensing, radar altimetry and radar backscatter have led to global coverage of the seas over time frames that can be considered as synoptic.

There is no doubt that sea-state projections, including directional wave spectral information, can be obtained and passed to ships and can then be transformed into a very useful form for ship operations and routing. I raise this point to emphasize a very important consideration. Ship operators do not care about the details of wave spectra. Their concern is the best way to get from one point to another with constraints on time, fuel, allowable possible ship damage and ability to perform their function. They can, for example, use spectral information in estimating ship damage or motion if the spectral information is convolved with their ship's response to a sea.

Near-surface currents can also be detected electromagnetically and the ability to deduce deeper currents by altimetry of the sea surface shows considerable promise. More will be said about this important work by Professor Wunsch in a later paper.

Those properties of the sea that are so important to acoustic underwater sensing are temperature, salinity and pressure. The speed of sound depends on them linearly to a first-order approximation. It gives rise to remarkably good propagation characteristics, especially at frequencies below, say, 5 kHz. The subtle changes in temperature and salinity seen in the ocean can have significant influence on sensor systems. The ability to infer these volumetric properties from remote sensing alone is questionable. But this is where measurements *in situ* coupled with large-scale oceanographic modelling on digital computers are useful. The judicious placement

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of strings of sensors will allow extrapolation to the rest of the volume and predictions into the future, provided that surface driving functions such as wind, cloud cover, precipitation, surface and atmospheric temperature are known. A knowledge of basin structure and major currents has been incorporated into dynamic models of the sea that are amenable to numerical computer coding for quantitative prediction. The successes that have been reported by large-scale modelling, even though it is still in its infancy, indicate great promise in this field both for prediction and parametric sensitivity studies (e.g. boundaries, rotation, currents, sea surface driving forces). By parametric variation, locations can be chosen for the placement of measurements *in situ*. The ability to process data at high rates at relatively low power requirements and to communicate either underwater or via satellite are now nearly state of the art. For military applications there is a need for continuous measurement and therefore the technology must provide either a low-cost 'expendable' or a long-term highly reliable alternative. Thus the combination of remote sensing, numerical modelling and *in situ* devices show great promise for a better understanding of the sea and therefore more intelligent fleet operations.

The paper by Wunsch addresses another means of measuring the sea. This offers another important alternative. It is probably with a combination of all methods that a nearly complete global-scale knowledge of the sea can be of use to making estimates of the best use of sensors and ships.

There is a need to proceed somewhat cautiously in the incorporation of this enormous wealth of potential information into fleet operations. It must be remembered that military operators and planners are faced with very complex decisions in which the sea conditions play only a part. Oceanographic data needs to be incorporated in a far more condensed form than it now is. This perhaps is not the direct responsibility of those in ocean technology, but it remains as a problem before the full impact of oceanographic data taking can be of use to the military. Oceanographers themselves have not met the full challenge of enormous data rates. A fine example of this is the current level of activity in understanding the data from Seasat, which was only 3 months duration in 1978! Much thought needs to be given in the 1980s to data reduction, distribution and its computer and communications architecture if the incorporation of all of these techniques is to have maximum impact on fleet operations in the 1990s.

Marine geology

One of the most important areas of further research in underwater acoustics is the effect of the sea floor on propagation and scattering. One only has to peruse the current acoustic literature to be aware of the large interest in the sea floor. The general trend is to relate acoustic models of propagation to so-called geo-acoustic models whenever sound interacts with the sea floor. These geo-acoustic models incorporate layering, densities, compressional and shear speeds, and attenuations. The direct measurements of these is of course difficult and expensive, so much is inferred from geophysical surveys and acoustics experiments. With many sensor systems using lower frequencies there is a need to understand the effects of layering to depths of the order of metres to tens of metres. Present measurement systems are not capable of this resolution. It is, however, within the capability of ocean technology to develop deep towed arrays and sound sources that can operate sufficiently close to the sea floor. It is also possible to develop cables capable of handling the data rates required.

One can observe that such methods will only allow low sampling rates that are brought about by the limitations on rate of advance and swathe width of a deep array. This clearly limits the coverage of sea floor and therefore the number of areas that can be surveyed in any reasonable period of time. Thus the types of sea floor that are measured must be selected carefully to allow the best extrapolation to other areas.

Since geo-acoustic models will be limited, this extrapolation must be based on the connection between these geo-acoustic models and the geology of the area. It is easy to see that a scientifically consistent understanding of the variation in geo-acoustic models will be through a geological model of the sea floors. This is especially evident in an area as complex as the western Pacific. More stress needs to be placed on the importance of geology to understanding the effects that the sea floor has on acoustic systems. There is no doubt that a geological investment will be more timely and less expensive than acoustic surveys of the world's oceans.

Marine atmosphere

Much of what concerns the military at sea has to do with the marine atmosphere and the sea surface. It is important in the detection of surface and above-surface targets as well as in communications with other ships or weapons systems. There is still much to be understood about the propagation of electromagnetic signals above the sea surface and therefore in the ability to estimate systems performance under varying conditions.

I find it difficult to separate atmospheric research and measurement from marine technology since measurements must be made in a marine environment. Measurements of the atmosphere are difficult at sea, apparently more difficult than those in the sea itself. Aircraft can be used but they are logistically complex, and generally expensive. I believe it requires larger investments than have been made in the past and then the clever use of marine technology.

Summary

There are many other areas of ocean instrumentation construction and research that will also affect the fleets of the world in the next decade. I have given my views on some of the most important. I do think that sharing ocean-wide data bases, including the taking of data that are purely oceanographic for military purposes, is feasible and will not compromise any nation's security. If for no other reason this could come about simply because of the enormous costs of gathering, reducing and disseminating data.

The oceanographers and technologists in the civilian sector should look to what the military is doing and exploit it for their own uses. If the military does place the requirement for world-wide ocean data and prediction high enough to implement elaborate systems the oceanographer will be in a position hitherto unknown to him: that of synoptic measurements over ocean basins with resolution sufficient to observe mesoscale effects. The geologist may have tools for sufficient resolution to understand better the processes of sedimentation. The exchange of technologies between the military and civil sectors has existed for most of the twentieth century: I see no reason to expect that it will change in the 1990s.

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Discussion

A. S. Laughton, F.R.S. (*Institute of Oceanographic Sciences, Godalming, U.K.*). In his talk Dr Goodman emphasized the importance of the sea floor and the need for a greater knowledge of its detailed shape. During the last 8 years the international non-military community has been reacting to a similar civilian need, to provide oceanographers and engineers with a comprehensive series of bathymetric charts covering the whole world. The Intergovernmental Oceanographic Commission and the International Hydrographic Bureau have just completed the 5th edition of the *General Bathymetric Chart of the Oceans* comprising 18 sheets at a scale of 1:10000000. To do this they have called upon the expertise of specialists in marine geology and ocean floor morphology from all over the world to bring together the best data available.

Throughout this operation, whose cost has been estimated at more than $8M, there has been a constant awareness that a similar (and possibly better) data base lies hidden in the archives of defence establishments and that much of the effort has been duplicated and perhaps unnecessary; and further that the multibeam swath mapping technology that was used by the defence agencies is now available commercially and that survey operations may be carried out in regions already covered by the military. Does Dr Goodman see that by the 1990s this substantial bank of good data obtained on public funds might be released and that a sensible cooperation by different parts of government organizations, in all involved countries, could be initiated to the benefit of all?

R. Goodman. The bank of data to which Dr Laughton refers is one of the few that has not been made available in its general form to the non-military community. It is because bathymetry identifies, obviously, geographic areas of military interest and because its uses were highly specific. It is of high quality and would therefore be of great use to the public and if available would, as Dr Laughton stated, prevent duplication.

I do foresee a gradual release of these data. My optimism is based on the facts that (1) many of the data are now more than 20 years old and (2) specific military requirements generally change over that time frame. Most data will be over 30 years old in the 1990s.

One of the basic difficulties in getting data released from the military is that of knowing what data exists. This almost requires a detailed knowledge of the data before one has seen it. Also the military are, by their nature, conservative and reluctant to give up data that either reveal a military development or offer an unfriendly nation an opportunity to gain data for military purposes at a very low price (to themselves).

Cooperation by different government agencies at an international level is probably the only way that the world can afford worldwide bathymetric charting. I do not foresee the military leading this effort but probably, if anything, being dragged reluctantly into it.