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SCIENCE & TECHNOLOGY

EUROPE

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[Selections from the Oceanology International 90 conference held in Brighton, UK, 6-9 Mar 90, sponsored by Spearhead Exhibitions]

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DEEP WATER DRILLING - UNDERSTANDING THE INFLUENCE OF CURRENTS

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1. Introduction

With the finite life of the oil resources in the North Sea, oil companies are expanding the horizons of their research beyond the UK shelf, into deep water areas which can present harsh environmental conditions in which to operate. One such region is the North-West Approaches, where the depths of water encountered on the continental slope are far greater than any experienced in the North Sea. Using semi-submersible drilling rigs, it has been possible to carry out trial drilling programmes in water depths of up to 700 metres. During these programmes, knowledge of environmental parameters affecting operations, such as currents and waves, are essential. This is particularly true in the North-West Approaches, where currents on the slope can be in the order of 1 m/s (2 Knots). To measure the variability of these currents through depth in real-time, in deep water, has always presented oceanographers and engineers with a variety of technical problems. These problems have been generally overcome by deploying a small number of current meters, cabled to the surface for real-time use. This has led to severe limitation in the amount of current data available in real-time and for subsequent design criteria studies. Furthermore, it has not been possible to identify detailed velocity/depth structure in the water column.

Fortunately, over the past few years, an instrument has become available which addresses most of these problems, and has led to a much greater amount of data being collected, together with easing some of the technical problems. This instrument is manufactured by RD Instruments and is known as the Acoustic Doppler Current Profiler (ADCP). ADCPs work on the principle of acoustic transmission of a precise frequency, enabling multiple measurements to be made throughout the water column by one instrument. The ADCPs are available at a number of different frequencies; the lower the frequency the greater the range. With this in mind, Wimpey Environmental purchased the lowest frequency version, operating at 75 KHz, which has a maximum range of around 700 metres. The profiling range may be extended by mounting a pair of ADCPs at middepth, pointing in opposite directions. This has been linked to our PC-based, real-time data acquisition package which has been designed for ease of use and user-specific displays. This system, combined with VAX-based post-processing routines, has provided operators and designers with much more realistic high resolution current profile data.

2. Principles of Acoustic Doppler Current Profiling

The Acoustic Doppler Current Profiler (ADCP) enables non-intrusive measurements of current profiles over depths of up to 700 metres. The ADCP measures Doppler frequency shift between acoustic pulses, transmitted by the instrument, and received return signals reflected from scattering particles such as plankton and suspended sediments in the water column. The frequency shift is then used to infer the local water velocity relative to the instrument.

The general principles of acoustic Doppler current profiling are illustrated in Figure 1. The ADCP acoustic transducers are set out in 'Janus' configuration; the four narrow acoustic beam paths are each projected at 30 degrees to the vertical and at equal 90 degree spacings in the horizontal plane. For each beam in turn, a short acoustic pulse is transmitted. The return signal represents the aggregate of a large number of individual reflections of the transmitted pulse, from scattering particles within the acoustic beam path. The time after pulse transmission at which an individual signal reflection is received at the instrument is the two way acoustic propagation time between the instrument and the reflector. With knowledge of the speed of sound propagation through seawater, it is possible to 'time gate' the reflected signal, thus segmenting it into a series of discrete measurement cells. The speed of sound propagation is calculated using instantaneous water temperature measurement at the instrument. A Fourier transform algorithm is applied to the time-gated return signal for each measurement cell to determine the signal centre frequency, and hence the Doppler frequency shift. As shown in Figure 1, the Doppler shift, DF, is related to the velocity components of scattering particles along the acoustic beam axis. From the four beam pattern projected by the ADCP, it is possible to infer three orthogonal components of water velocity for each measurement cell. It is assumed that the velocity field is constant across the four beam projection area of an individual measurement cell.

It is assumed that the speed of sound in water, calculated for the position of the ADCP, is constant through the water column. In reality there will be a small amount of variation due to temperature, salinity and pressure differences with depth. This leads to a small uncertainty and variability associated with the depth limits for each measurement cell. However, this is of little significance in terms of resultant data quality.

One limitation of the ADCP is its inability to resolve flow velocities in the vicinity of a boundary; this being the seabed for downward-looking applications, and the sea surface for upward-looking systems. Within 15% of the total distance between the profiler and the boundary, the doppler-shifted acoustic return becomes contaminated with direct reflections from the boundary, emanating from ADCP transducer sidelobe emissions. This means that a downward-looking profiler cannot measure near-bed currents, and an upward-looking profiler cannot measure near-surface currents. The instrument manufacturers are currently conducting research into acoustic techniques to eliminate this limitation.

3. ADCP Configuration

A typical deep water ADCP deployment configuration is shown in Figure 2. The instrument is suspended below the semi-submersible drilling vessel on tensioned guide wires, and transmits its acoustic beams towards the sea bed. Great care must be taken that the acoustic beams do not impinge on the drill riser as this will corrupt the measurement. The datum for measurement cell depths is relative to the drilling vessel. During an instrument deployment, the vessel datum will move vertically relative to the sea bed, due to tidal elevation and degree of ballasting. However, such movement is small in relation to measurement cell depth, and is not generally necessary to compensate for.

The ADCP operational parameters are set up by serial communication from a PC on board the vessel. Parameters such as cell length, acoustic pulse length, data averaging period and signal-to-noise ratio threshold for rejection must be carefully configured for the specific application in order to optimise data quailty. A degree of data quality control is performed within the profiler to reject obviously erroneous returns; further QC is conducted within the surface display and analysis software.

4. Computer Installation, Real-Time Displays and Data Logging

The real-time displays are custom designed to provide drilling engineers and those concerned with sub-sea operations with a clear and easily interpreted view of current velocities throughout the water column. The complete system is designed around an IBM compatible PC running 'Windows 386' software. This is a multitasking software environment in which a number of different programs can run concurrently. This means that data logging can proceed as a background task, even when various programs are accessing recorded data files. The display menu and various available screens are shown in Figures 3 and 4.

Data may be displayed to show short- or longer-term trends in flow, either at specific depths, or in profile through the water column. The various displays are selected from a simple menu (Figure 3a) using function keys, and are quite suitable for use by an unskilled operator; it is important in such an application that displayed information is in a form which is readily understandable to all potential users.

The default display (Figure 3b) shows the most recently derived velocity profile. Profiles are shown for current speed and direction, and also combined in the form of an isometric profile. Short-term time histories of current speed and direction can be displayed at four selected depths (Figure 3c); this display is particularly useful for monitoring the development of non-uniform flow. Longer-term current speed time histories can be displayed for two selected depths, in order to review anticipated tidal flow development (Figure 4a). The time histories are presented in the form of a comb, each vertical line is coloured according to speed magnitude, and represents an individual ADCP record. The fourth display shows recorded current data in the form of sequential isometric vector profiles (Figure 4b); these are of use in interpreting the ambient flow condition, especially where complex high frequency shear flow occurs. The final display (Figure 4c), shows a colour contoured time history of speed through depth. This is a concise representation of the vast amount of data collected by the ADCP, and is ideal for the review of previous non-uniform flow events.

This system has proved to be extremely useful during various offshore activities, particularly for monitoring the development of unpredictable non-tidal flow conditions which may impede operations.

5. Data Analysis, Presentation and Interpretation

Acoustic current profiling technology has only been adopted in the offshore industry over the last 3 or 4 years. Numerous validation exercises have been conducted (Ref 1) such that the user can now have a high degree of confidence in the instrument accuracy and reliability. However, understanding and exploitation of the full potential of Doppler profiling are still developing. Similarly, methods of analysis, representation and application of the data derived are in a state of evolution.

The ADCP measures current speed and direction for each selected depth cell. The data set recorded is therefore equivalent to that derived from a vertical string containing a large number of equally-spaced recording current meters; this provides comprehensive information on the temporal variability of current depth profile and offers a challenge in terms of concise and useful presentation formats.

For deep water studies, current flows may be classified in 3 event scale categories:

i) High frequencies (internal waves);
ii) Tidal frequencies (semi-diurnal, diurnal internal tides);
iii) Low frequencies (density driven flows, surges, Meso-scale eddies).

All of the above components are of importance in the overall current profile. Different forms of presentation are appropriate for studying processes at each of these scales. In Figure 5, data are shown in the form of discrete current speed time histories for each measurement cell. This presentation is particularly useful for identifying tidal current characteristics, and also high frequency events such as that evident in cells 1 to 5 on day 2. Stacked time series plots of current speed and direction are very useful for initial data quality assessment but can prove to be extremely large and unmanageable for long-term deep water deployments. Sequential isometric vector plots, such as that shown in Figure 6, combine speed and direction profile information and indicate its variation with time. Such plots can help to interpret flow patterns at both high frequency and tidal frequency event scales. The event shown in Figure 2 suggests the passage of an internal wave; a significant shear profile is seen to develop which could cause significant transient loading on a mooring or drill riser.

For operational purposes, it is often useful to be able to characterise anticipated deep water current profiles with respect to tidal time. This can be achieved by statistical analysis of an ADCP dataset to produce a series of typical Spring and Neap tide profiles (Figure 7) for each tidal hour. Such analysis is of use in estimating tidally-induced flows but does not enable the prediction of non-tidal phenomena.

The composite plot shown in Figure 8 provides a concise representation of the substantial amount of information collected using an ADCP. Colour contoured graphs of current speed or velocity, on depth and time axes, illustrate temporal flow variation at tidal and lower frequency event scales. The combination of scalar speed and orthogonal velocity components can reveal much about the local flow regime; such information can also be presented alongside time histories of various other associated parameters such as meteorological conditions, sea state and tidal elevation.

For structural monitoring and design purposes, it may be important to assess the occurrence and magnitude statistics for various types of current profile patterns. The use of depth-averaged current parameters, together with an idealised velocity/depth shear profile may be adequate for many North Sea applications. However, in more complex deep water environments, where flow direction may vary substantially with depth, it would seem necessary to derive more comprehensive flow profile descriptors. As exploratory drilling in deep water locations increases, it is likely that further attention will be given to flow profile characterisation for engineering applications.

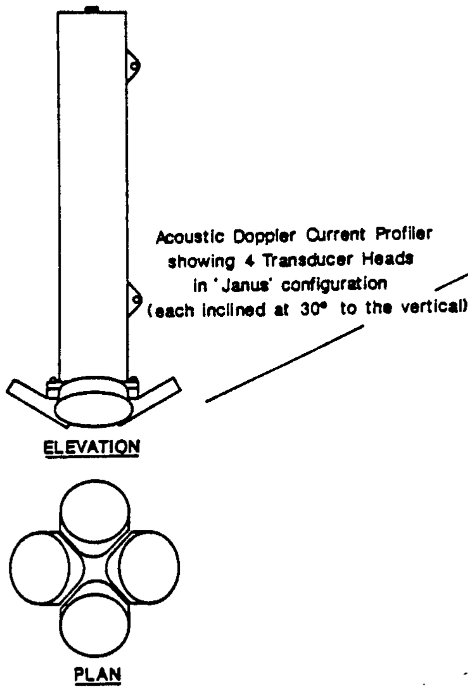
With oceanographic measurements in the offshore industry, a series of fairly standard descriptions and presentations have evolved for data derived from wave buoys, tide gauges and current meters. The use of acoustic current profiling is still in its infancy, but shows tremendous potential, especially in deep water applications. It is likely that there will be significant advances towards appropriate industry standard current profile descriptions during the next few years.

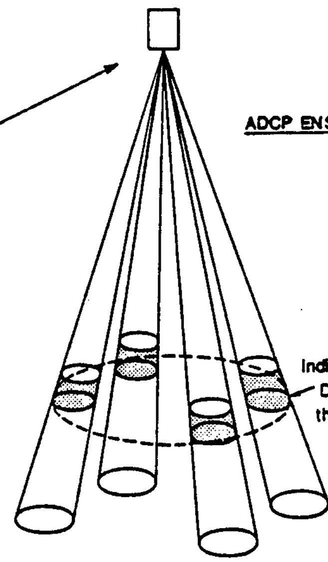
6. Conclusion

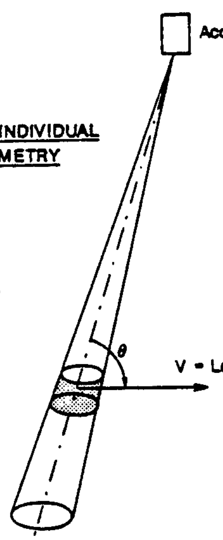
The ADCP offers significant scope for current profile data acquisition in real time, in water depths of up to 700 metres. It is of particular use during drilling activities in deep waters on the continental shelf edge, where variable and unpredictable flows can impair operations. Concise profile displays in real time can greatly assist the planning of various hazardous activities such as riser deployment and recovery. Detailed post-processing of ADCP data can help to identify typical flow profile characteristics for a particular area. Some developments have already been made in the representation of deep water current profile information but further consideration is needed in this area by oceanographers, drilling operators and structural engineers to optimise the full potential of the ADCP.

7. References

1. **RD Instruments, 1989**
   'Acoustic Doppler Current Profilers - Principles of Operation.



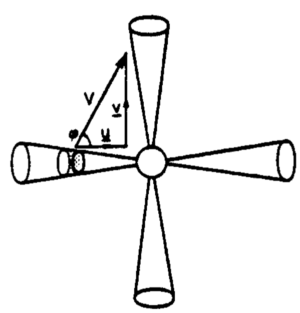




Local horizontal particle velocity V can be resolved into 2 orthogonal beam-aligned horizontal components :

$$\underline{u} = V\cos\varphi$$

$$\underline{v} = V\sin\varphi$$



The component of $\underline{u}$ or $\underline{v}$ along the beam axis is related to the Doppler frequency shift in the return acoustic signal, Δf

$$\Delta f = \frac{2f_T(\underline{u}\cos\theta)}{c}$$

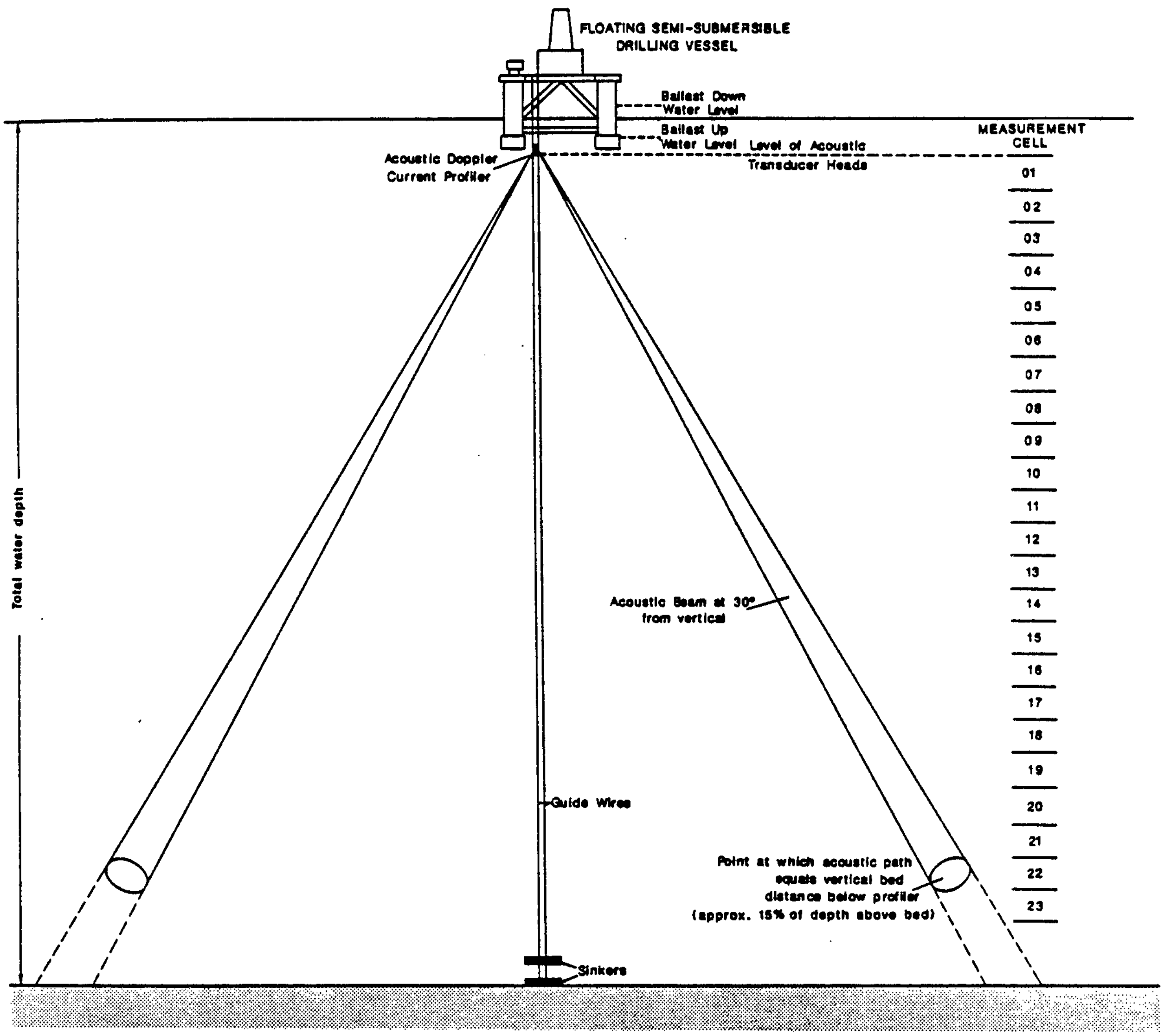
PLAN VIEW OF BEAM GEOMETRY

Where :

f_T = Transmitted signal frequency

c = Velocity of sound in water

Note : For simplicity, the above derivation considers only the 2 horizontal components of velocity. In practice the ADCP also resolves the vertical component $\underline{w}$


FLOATING SEMI-SUBMERSIBLE
DRILLING VESSEL
Ballast Down
Water Level
Ballast Up
Water Level
Level of Acoustic
Transducer Heads
Acoustic Doppler
Current Profiler
MEASUREMENT
CELL
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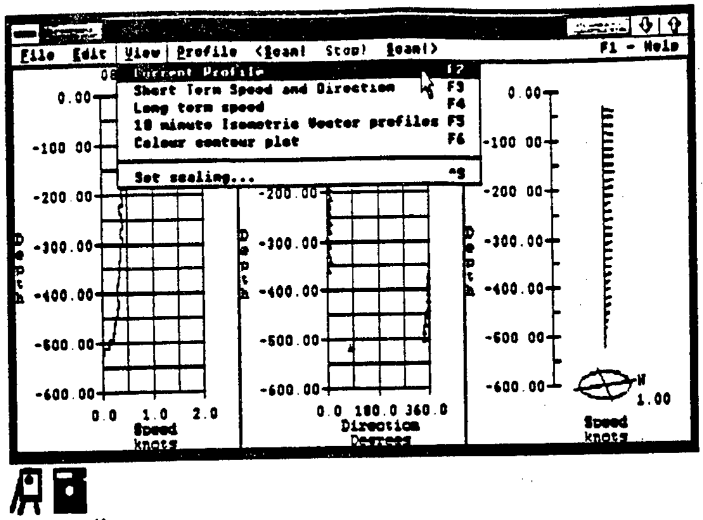
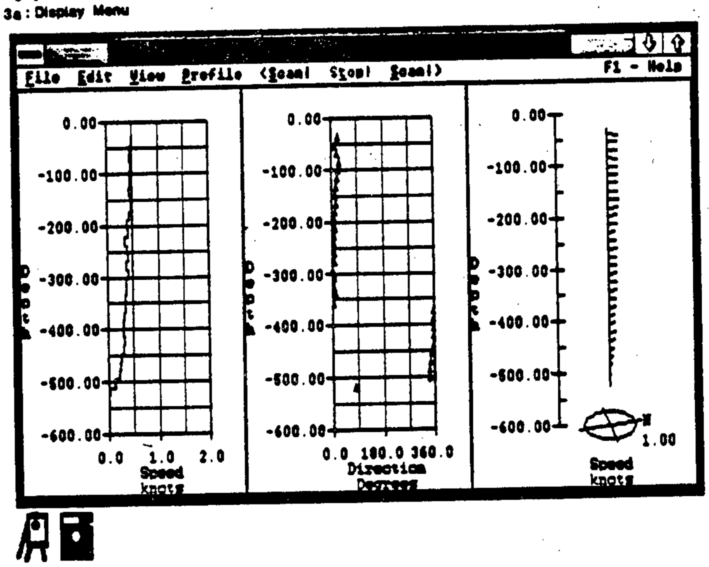
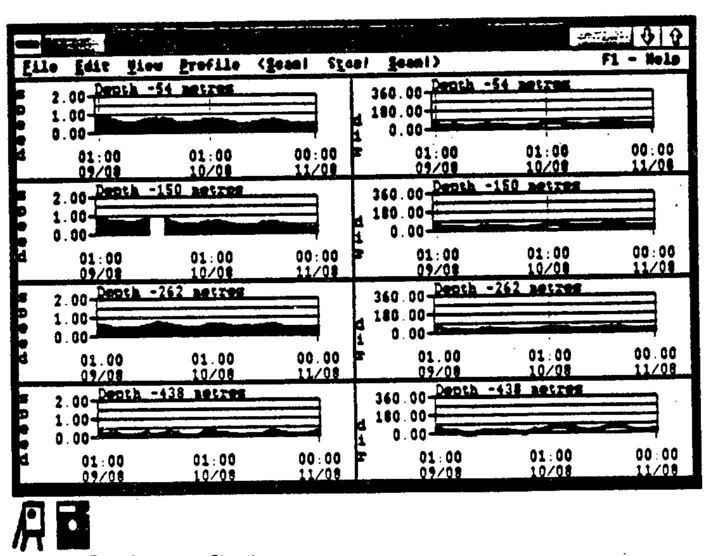
23
Total water depth
Acoustic Beam at 30°
from vertical
Guide Wires
Point at which acoustic path
equals vertical bed
distance below profiler
(approx. 15% of depth above bed)
Sinkers



3a : Display Menu



3b : Current Profile



3c : Short Term Speed and Direction

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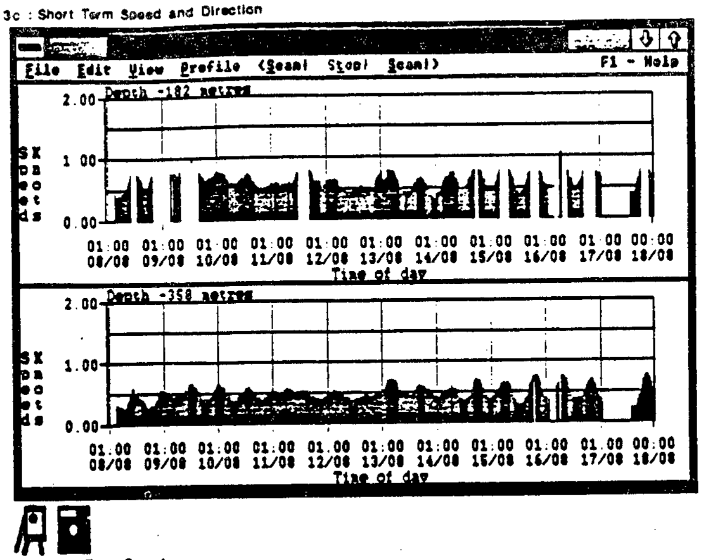
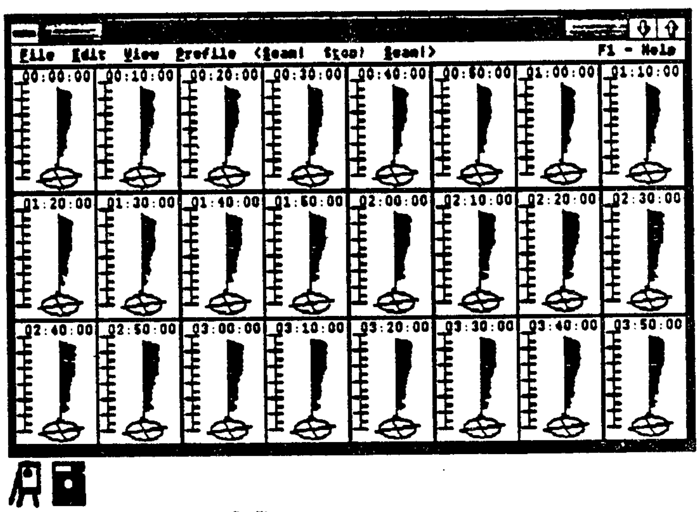
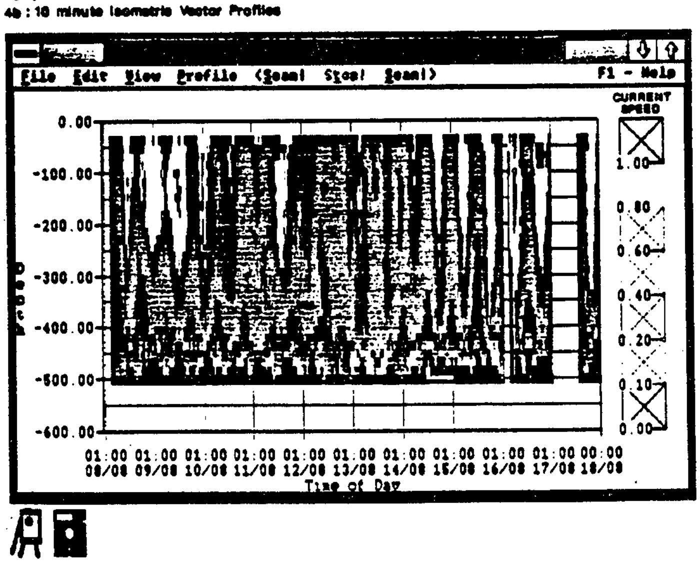


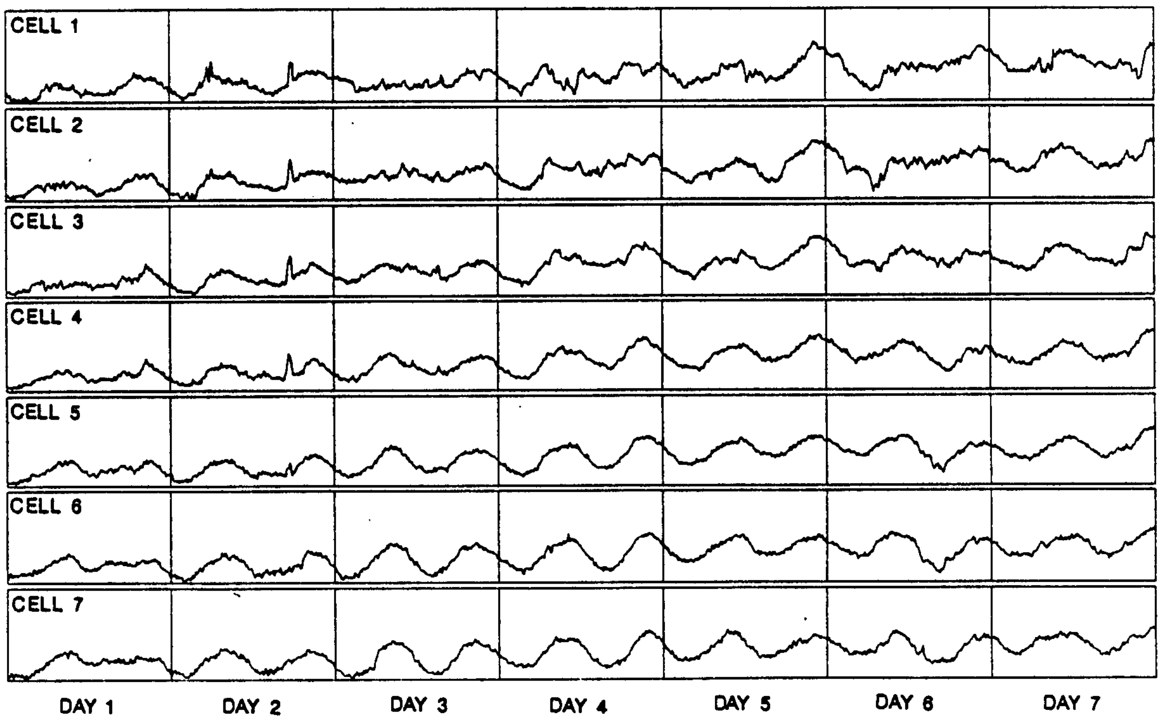
4a : Long Term Speed



4b : 10 minute Isometric Vector Profiles



4c : Colour Contour Plot


CELL 1
CELL 2
CELL 3
CELL 4
CELL 5
CELL 6
CELL 7
DAY 1
DAY 2
DAY 3
DAY 4
DAY 5
DAY 6
DAY 7

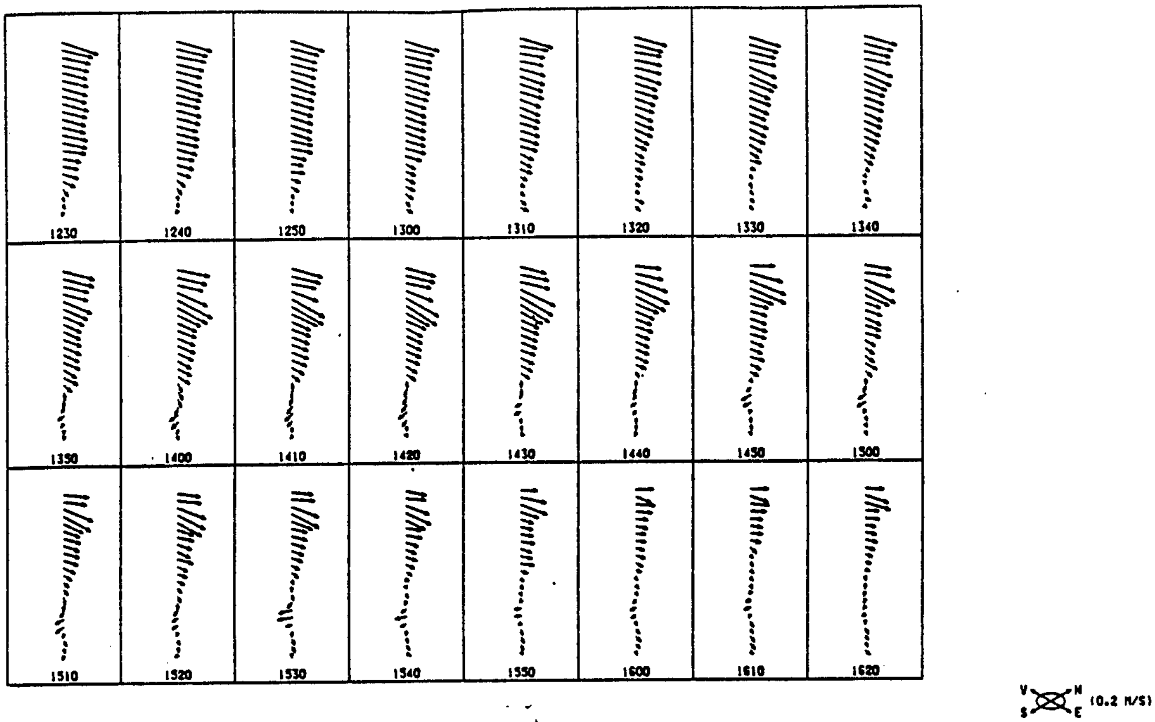
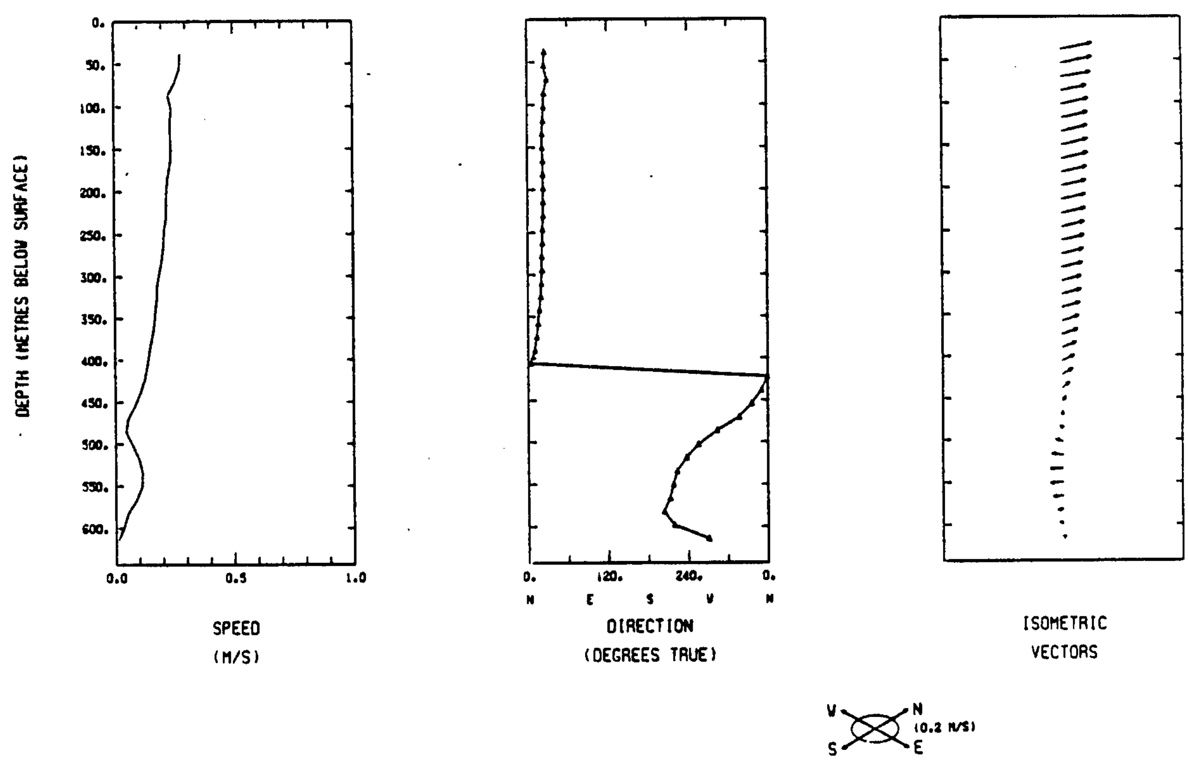
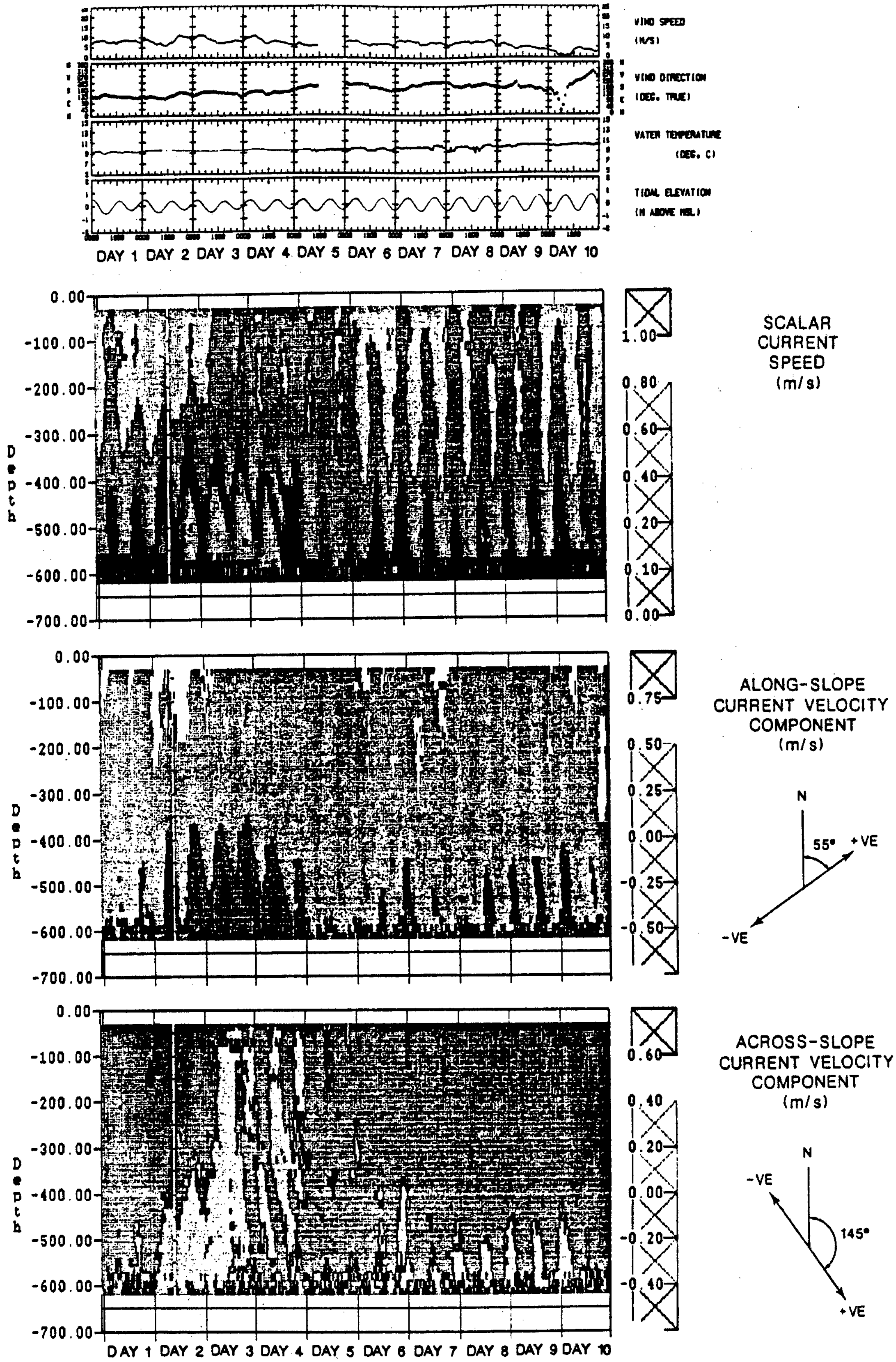


Figure 6 : 10 MINUTE ISOMETRIC VECTOR PROFILES




WIND SPEED
(M/S)
WIND DIRECTION
(DEG. TRUE)
WATER TEMPERATURE
(DEG. C)
TIDAL ELEVATION
(M ABOVE MSL)
DAY 1 DAY 2 DAY 3 DAY 4 DAY 5 DAY 6 DAY 7 DAY 8 DAY 9 DAY 10
Depth
0.00
-100.00
-200.00
-300.00
-400.00
-500.00
-600.00
-700.00
1.00
0.80
0.60
0.40
0.20
0.10
0.00
SCALAR
CURRENT
SPEED
(m/s)
0.75
0.50
0.25
0.00
-0.25
-0.50
ALONG-SLOPE
CURRENT VELOCITY
COMPONENT
(m/s)
N
55°
+VE
-VE
0.60
0.40
0.20
0.00
-0.20
-0.40
ACROSS-SLOPE
CURRENT VELOCITY
COMPONENT
(m/s)
N
-VE
145°
+VE

AUTOSUB - THE NERC COMMUNITY RESEARCH PROJECT TO DEVELOP AUTONOMOUS UNDERWATER VEHICLES FOR MARINE SCIENCE IN THE DEEP OCEAN

P.G. Collar[1] , A.R. Packwood[2] , D.D. Blane[3]

INTRODUCTION

Progress in our understanding of the role of the oceans in the global climate will depend vitally on the provision of large scale data sets which can be used to initialize and validate the global numerical models presently under development. The advent of Earth observation satellites such as the ERS-1 will do much to fulfil the requirements for sea surface data, while for measurement at depth new instrumental techniques are being developed. Acoustic tomography (Spindel and Worcester, 1986), for example, will enable the three dimensional temperature field to be inferred from sound speed measurements and may also provide direct measurements of currents at large scales. But these developments alone will supply neither the range nor the quantities of data which will be required from the ocean depths.

In the exploration of the ocean floor - which is crucial to a better understanding of the geological processes at work in the underlying crust - the images produced (Reference 1) by the highly successful GLORIA long range side scan sonar epitomize the recent development of remote acoustic sensing. In turn these images stimulate the requirement for observation of the ocean floor at greatly enhanced resolution.

For many of these developments - as well as for more traditional methods - the presence of a surface vessel will continue to be essential. Although for some types of measurement ships of opportunity and voluntary observing ships are used to good effect, the major contribution to observational programmes is at present made by research ships or dedicated charter ships. Of these there are but few in relation to the data collection tasks which lie ahead but they nevertheless represent a major investment in terms of the budget available for science. Hence the number of ships available globally is unlikely to increase significantly beyond present numbers and this will provide a limit to data collection capabilities.

In devising future data collection strategies particular attention will have to be paid to the polar regions - waters beneath the Arctic ice cap and the extensive Antarctic ice shelves - which play an important part in the processes governing global climate. These regions present a particularly severe challenge in that they are virtually inaccessible to existing measurement techniques, ship-based or otherwise.

THE AUTOSUB PROJECT

A new approach to data collection is clearly required in order to fulfil its perceived needs for the future NERC has initiated the Autosub Community Research Project. This seeks to take advantage of advances currently being made in a range of enabling technologies such as materials, global position determination and data telemetry, and robotics. The aim is to establish a capability for the routine, cost-effective collection of physical, chemical, biological and geophysical data from the deep oceans using fully autonomous, unmanned submersibles (McCartney and Collar, 1989).

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Two missions provide conceptual goals for the project, effectively representing the end points of a range of possible missions. The first addresses the requirements of climate research programmes, and embodies the concept of the Deep Ocean Long Path Hydrographic Instrument (DOLPHIN), which will navigate its way across the oceans, conducting a continuous series of hydrographic measurements. DOLPHIN will undulate between surface and ocean bed, surfacing at intervals in order to receive information on its position from the GPS-Navstar satellites and to report on the status of its internal systems. The basic undulating cruise profile will be repeated at intervals of about 30 km, in order to resolve the density structure associated with the mesoscale eddies. The data obtained from vehicles like DOLPHIN will contribute directly to large scale international programmes such as the World Ocean Circulation Experiment, due to take place during the decade 1990-2000.

The second mission is directed at the extension of acoustic remote sensing techniques in the exploration of the deep ocean floor. The GLORIA towed side scan sonar produces images of a 50 km wide swath of ocean bed centred on the ship's track. The aim of the Deep Ocean Geological and Geophysical Instrumented Explorer (DOGGIE) is to enable features identified in a GLORIA primary survey to be investigated at much finer spatial resolution. Deep towed instrument techniques applied to this task are both slow and cumbersome due to the length of the towing cables required. The DOGGIE, operating autonomously from a mother ship, will be free of the constraint of a towing cable, and will release the ship to carry out other tasks concurrently with the DOGGIE mission. During a 3-5 day mission DOGGIE will cruise at a height of about 500 m above the ocean bed and will cover an area of perhaps 50 km x 50 km. A representative sensor payload would include multi-frequency side scan sonars, a sub-bottom profiler and a magnetometer.

The Autosub project is structured in four phases and is currently in the early stages of the second phase. Phase I comprised a series of 26 feasibility studies, focussed principally on the vehicle subsystems, which sought to identify the key areas in which research and development would be required. These also provided an improved basis for estimating costs, timescales and levels of risk. Other major tasks during this period included an analysis of the wider range of potential science applications for autonomous vehicles - part of the essential and continuing liaison with the science community; and the preliminary examination of any possible future constraints on the operation of autonomous unmanned vehicles (AUVs) on the high seas. In order to achieve success in the project it is important that appropriate expertise should be drawn in wherever this can be found: contributions to Phase I have been made by university and industrial research groups (see Acknowledgements) as well as by the host laboratory for the project, IOSDL. It is not possible to present detailed results from the studies in this short paper. But in the following sections some of the more important aspects are briefly outlined insofar as they are likely to influence the future direction of the project.

VEHICLE CHARACTERISTICS

The accompanying illustrations (figs. 1 and 2) show the two conceptual vehicles as they have evolved during the course of the studies. DOLPHIN is nominally 6 m in length and 1.2 m maximum diameter; this represents a starting point from which to examine factors relating to energy storage and buoyancy, rather than a design objective. At 8 metres in length, DOGGIE is the maximum size permissible if it is to be handled by a NERC research vessel. Neither vehicle outline represents a completed design; rather, each serves as a focus for developing ideas. The disparate nature of the two missions is clear, but there are in fact substantial common elements in the sub-systems. For example, it is intended that both

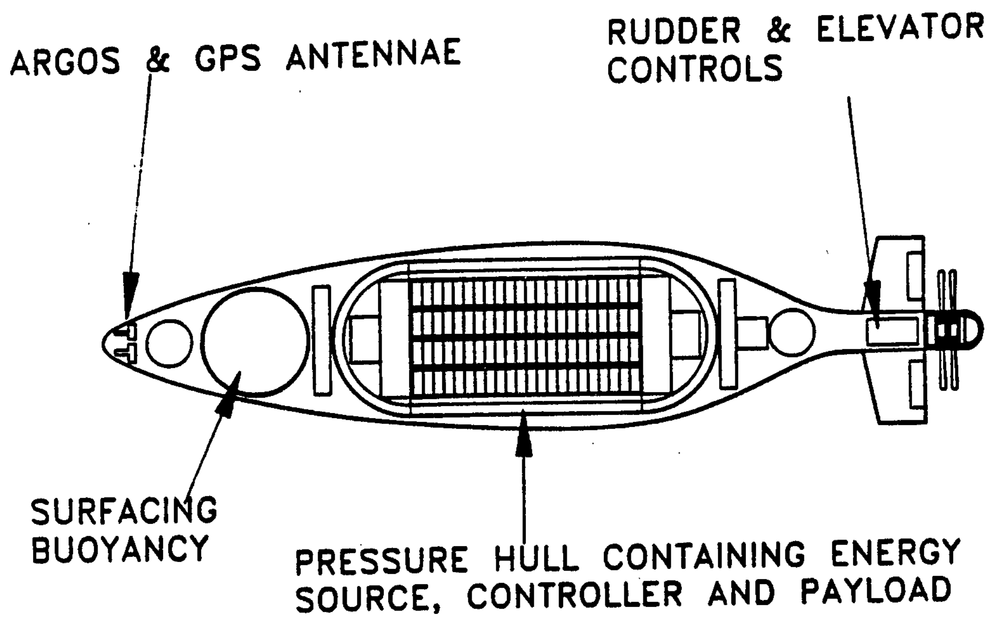

Fig. 1 DOLPHIN Vehicle

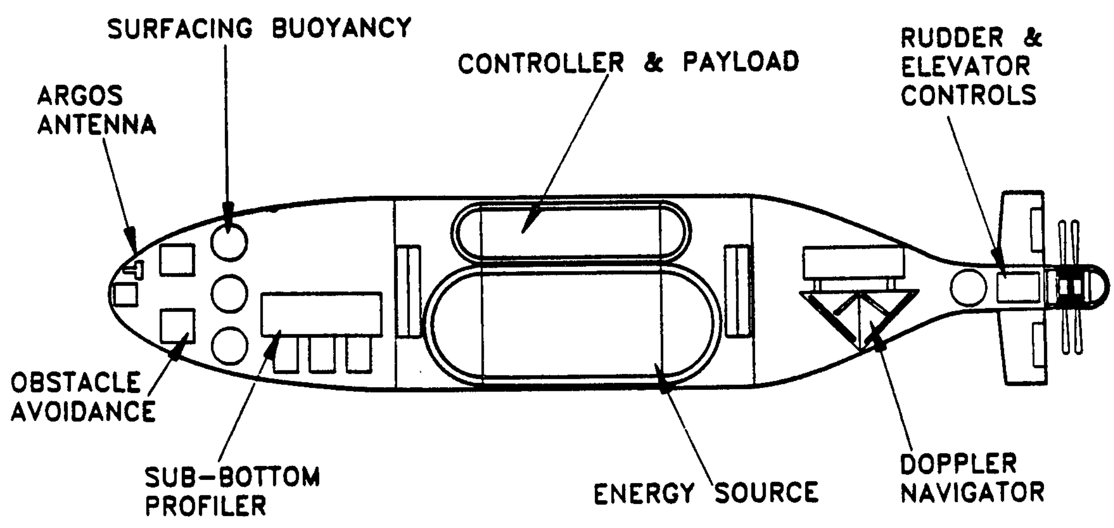

Fig. 2 DOGGIE Vehicle

vehicles should be made essentially neutrally buoyant at all depths and that propulsion should be effected using torque balanced contra-rotating propellers driven by brushless dc motors. Directional changes in vehicle motion should be brought about by a combination of transfer of mass (mercury) within the vehicle and by adjustment of control surfaces. In its internal layout each vehicle has been provided with a single pressure vessel, since an additional and vital function of the pressure vessel is to provide buoyancy. The inclusion of a single pressure vessel represents the most efficient way of providing this. In other respects, however, the hull forms differ appreciably. In DOLPHIN the pressure hull and outer hull provide mutual support, while DOGGIE has a substantial space frame on which the acoustic arrays are mounted and which also supports the pressure vessel. The outer hull in this case is very lightly stressed. The reasons underlying the differing hull forms are now examined.

HYDRODYNAMICS

For both vehicle concepts (DOGGIE & DOLPHIN) an efficient hydrodynamic shape with an integrated propulsion system will be required in order to obtain maximum endurance for the available energy. For DOLPHIN in particular this is critical if an entire ocean basin is to be traversed. The search for a minimum drag solution for underwater vehicle design is not new. Carmichael (1966) reported tests on a hull shape with 50% laminar flow that had half the drag of a conventional 'turbulent' flow torpedo at similar Reynolds number. Carmichael's hull was not optimized for minimum drag and therefore further drag reductions through hull shaping were potentially available at moderate Reynolds numbers, R_V, in the range $10^6 \le R_V \le 10^7$. Parsons et al (1974) determined, within certain parameters, the optimum shape for minimum drag. Designated X-35, this was optimized for $R_V = 10^7$ and had 70% laminar flow. Fig. 3 shows the outline of both X-35 and Carmichael's hull, the predicted drag of X-35 was $^2/_3$ that of Carmichael's hull.

With knowledge of this work, Alers (1981) attempted a full system optimization to determine best volume, Reynolds number, energy source and propulsion system, taking cost and energy expenditure as the main criteria. He concluded that for the laminar hull a volume of 3.5 m^3 and cruise speed of 2.5 m/s, giving $R_V = 2.5 \times 10^6$, were near optimum for a battery powered vehicle with conventional propeller. The hull, which became known as the Underwater Free Swimming Submersible (UFSS), was model tested in a towing tank, verifying a volumetric drag coefficient of 0.007 for the unpropelled hull at $R_V = 2.0 - 2.5 \times 10^6$. This is $^1/_3$ that of a conventional turbulent flow hull.

The UFSS hull was optimized for minimum drag of the unpropelled hull. It is generally accepted nowadays that by coupling the propeller closer to the body the overall performance can be improved by allowing the hull-propeller interaction effects to stabilize the turbulent boundary layer upstream of the propeller and improve propeller efficiency. Hence there is scope for further improvements to the after-body of UFSS to increase vehicle performance. A number of more exotic, active drag reduction methods such as suction and polymer injection have also been considered but a porous hull would probably become blocked by particulate matter and the volume of polymer needed to give sufficient drag reduction to be worthwhile would exceed the volume of the proposed vehicle.

All of these studies point out the benefits of a laminar flow hull but a number of uncertainties exist regarding the stability of a laminar boundary layer in the ocean environment. Laminar flow can be destabilized by surface roughness, turbulence and particulates. In addition very little is known of particle adhesion and accretion in the deep ocean on smooth moving surfaces. All of these factors represent risks to the maintenance of low drag. From the relatively sparse data available on oceanic turbulence and particulate size and distribution it is thought that levels of both may be sufficiently low in mid-water in the deep ocean not to adversely influence the laminar flow. Nevertheless, the data provided by the earlier tests on Carmichael's hull (Fig. 4) provide some encouragement in this respect. However, further research and more data are needed in order to assess the risks more fully.

ENERGY

The large uncertainties in the minimum drag force which might ultimately be achieved make realistic engineering calculations difficult at present. But if it is assumed that laminar flow can be consistently maintained then an overall target volumetric drag coefficient of 0.014 - which includes the drag of control surfaces - is not an unreasonable figure to adopt in making initial estimates of the energy requirements of DOLPHIN. On this basis, assuming reasonable levels of efficiency, the propulsion energy requirement for a 6000 km transect of a 6 m long laminar flow DOLPHIN vehicle (fig. 1) of 3 m^3 volume would be ~350 kW-hr. When the energy requirements associated with control, navigation and science payload are taken into account the total increases to ~400 kW-hr.

The situation for the DOGGIE vehicle (fig. 2) is different in that the hull size and shape are constrained by the need to accommodate sidescan and sub-bottom acoustic profiler arrays. These are less easily mounted in a laminar flow body, although this possibility is presently being investigated. The propulsion energy requirement for DOGGIE has been estimated to be ~200 kW-hr. Subsystem and payload requirements add a further ~100 kW-hr, making a total of 300 kW-hr.

A review of a wide range of energy sources shows (in summary, Table I) the practical options for DOLPHIN and DOGGIE to be very limited at present: a source satisfactory in all respects does not exist. In view of this we propose to use batteries initially and in this way minimize technological risk at a critical time in the development programme. Present battery technology does not, however, represent a viable option for full ocean missions. Taking as an example Lithium Thionyl Chloride cells which have energy densities of ~0.4 kWhr/kg and ~900 kWhr/m^3, it can be seen that a minimum battery payload for each vehicle mission would be of order 1 tonne, and would cost in excess of £100K. Once realistic packing densities are allowed for, the volume required would occupy all the space available within the pressure hull of a 6 m vehicle. The use of inherently more stable Lithium Sulphur Dioxide cells would reduce the energy capacity by a factor of about 1.5.

Several measures which would ease the energy supply problem, are, however, open to investigation. These include the acceptance of a reduction in operational speed, U (Drag $\propto U^2$), increasing vehicle volume, V (Energy storage $\propto V$, Drag $\propto V^{2/3}$).

Fuel cell technology - probably the Permeable Membrane Exchange cell - has been identified as having greatest promise for the longer term. Here the problems are associated with developing suitable means of storing and handling the fuels under 0-600 bar ambient pressures rather than with the fuel cell itself.

BUOYANCY

The projected use of batteries in the early phase of deployment also has implications for the buoyancy of the vehicles. Studies are currently in hand of the feasibility of pressure balancing batteries within a light, oil-filled container, so as to reduce the amount of buoyancy which would be

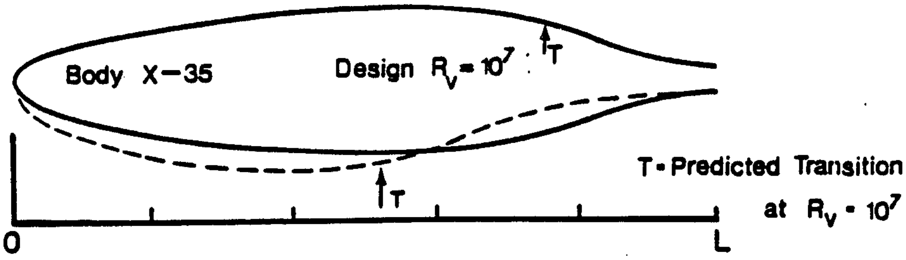

Fig. 3 The X-35 body optimized for $R_V = 10^7$ and the Carmichael vehicle (broken line) (after Parsons et al. (1974))

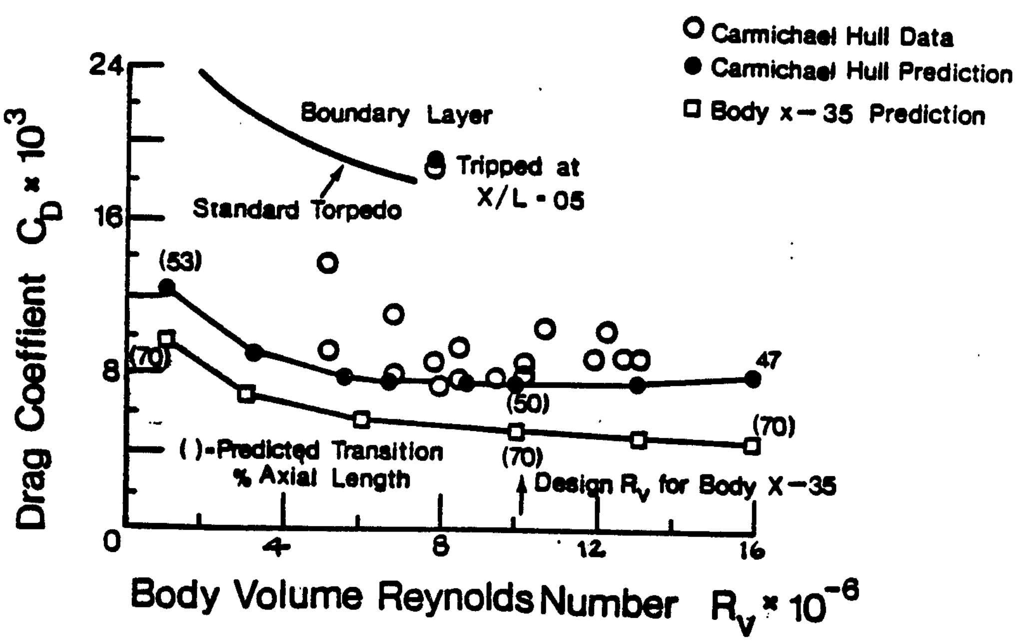

Fig. 4 Volumetric drag coefficient variation with Reynolds number for Carmichael's Dolphin compared with standard torpedo data and predictions for the X-35 (after Parsons et al (1974))

TABLE 1: VEHICLE ENERGY SUMMARY

High energy density primary batteries/motor	Available; reliable; high running costs. Safety precautions required. Lithium Thionyl Chloride cells present significant hazards.
Secondary batteries/motor	Under development. Energy densities of existing batteries too low. Low running costs. Reliable.
Closed cycle diesel	Present operating depth too shallow (~500 m). Autosub power requirements below minimum viable size (~10kW). High development costs. Running costs low.
Thermal source/Stirling engine	Under development: but at larger power than required; present operating depth inadequate; reliability unknown.
Fuel cell/motor	Permeable Membrane Exchange cells available. Ambient temperature reaction. Fuel storage, handling, disposal require considerable development. Safety aspects require consideration. Therefore presently high risk.
Radio isotope/thermoelectric	Available but inefficient and bulky. Not environmentally acceptable.
Nuclear fission	'Miniature' reactors in existence, but too bulky for present use. Environmentally unacceptable.

needed were they contained inside the pressure hull. Pressure balancing is a well established technique for certain types of battery but may not prove suitable here. If so, the pressure vessel or vessels will need to supply a buoyant force well in excess of 1 tonne. Seawater increases in density by about 3% between the surface and 6000 m depth as a consequence of its compressibility. So for a vehicle of 3 m^3 displacement, neutrally buoyant at the surface, a reduction in displacement of approximately 90 kg will be needed if neutral buoyancy is to be sustained to 6000 m depth. It is hoped that in order to save energy a substantial fraction of this can be met by the careful design and selection of material compressibilities within the vehicle. The pressure vessel study has shown that materials used hitherto in the deep sea - high strength steels, aluminium - even titanium - will not provide adequate buoyancy for the present task. It will be necessary to employ much lighter materials and the application of either fibre reinforced composites or metal matrix composites is indicated. On grounds of cost and state of development glass or carbon fibre reinforced composites are the more likely option. Relatively little is yet known of the behaviour of such materials under very high cyclic pressures in sea water - and particularly of their fatigue properties - and so a development programme will be required in this area.

MISSION MANAGEMENT

Conventional tethered vehicles are controlled in flight by a human operator, who must learn the idiosyncracies of different craft and of the same craft under different conditions. The operator monitors vehicle and subsystem performance in relation to overall system goals and takes appropriate decisions. Autonomous underwater vehicles like DOLPHIN and DOGGIE, on the other hand, have to meet these requirements for control and mission management without human intervention.

Technological difficulty and risk depend strongly on the complexity of the mission. In this respect, the requirements of the DOLPHIN mission are relatively straightforward. The DOGGIE missions, on the other hand, are related in difficulty to the geological environments in which the vehicle will be deployed. These range from horizontal flight above flat abyssal plains, to the negotiation of the rugged topography of continental slopes and mid-ocean ridges, demanding a high capability in terrain following, navigation and obstacle avoidance.

The Mission Management System - shown conceptually in fig. 5 is the core function into which the major subsystems feed information and from which they receive high level instructions. As yet, the methods required for its implementation are not well established, particularly in areas such as Artificial Intelligence (AI) techniques and the design of distributed computer systems.

A key decision will be how to balance the risks of AI technology against the potential benefits. These include the ability to undertake a mission of greater complexity and a greater capacity to respond to unforeseen events in an optimum way, thereby reducing the probability of premature mission abort. Another key decision concerns the choice of software architecture. Broadly there are two choices: in a hierarchical structure (fig. 6) each level issues commands to the next lower level and receives from it communications. The scope and generality of the commands and the abstraction of the communications increase towards the higher levels. In a heterarchical structure the communication and command routes are much less rigidly defined: an example is the Blackboard Control Architecture (Hayes-Roth, 1985) which has received considerable attention for autonomous land and marine vehicles, although in practice its inherent complexity will reduce software reliability. For subsea vehicles the hierarchical architectures are closer to realization (e.g. Durham et al., 1987). However, some of these decisions can be deferred since they will

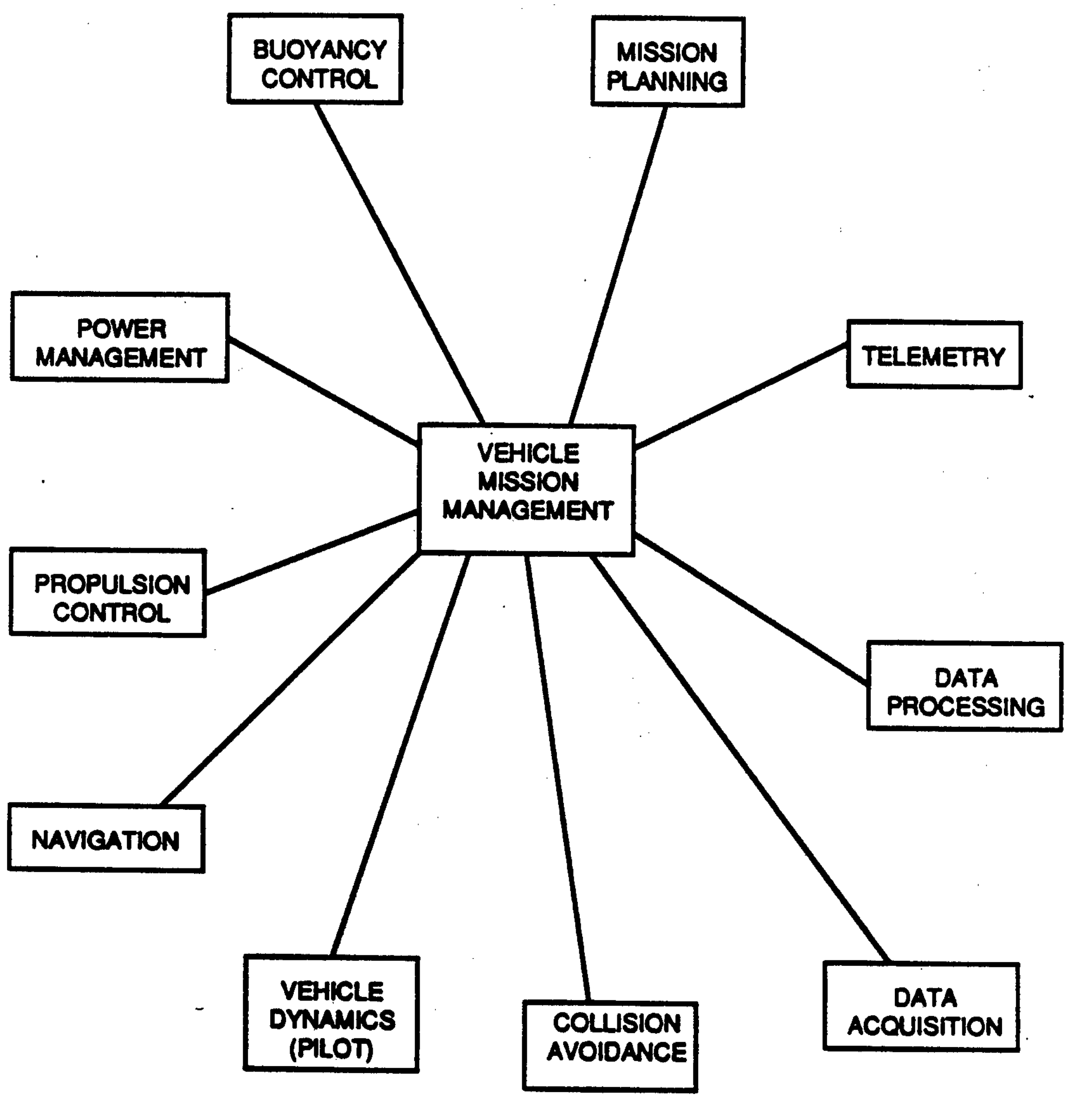

Fig. 5 Mission Management System

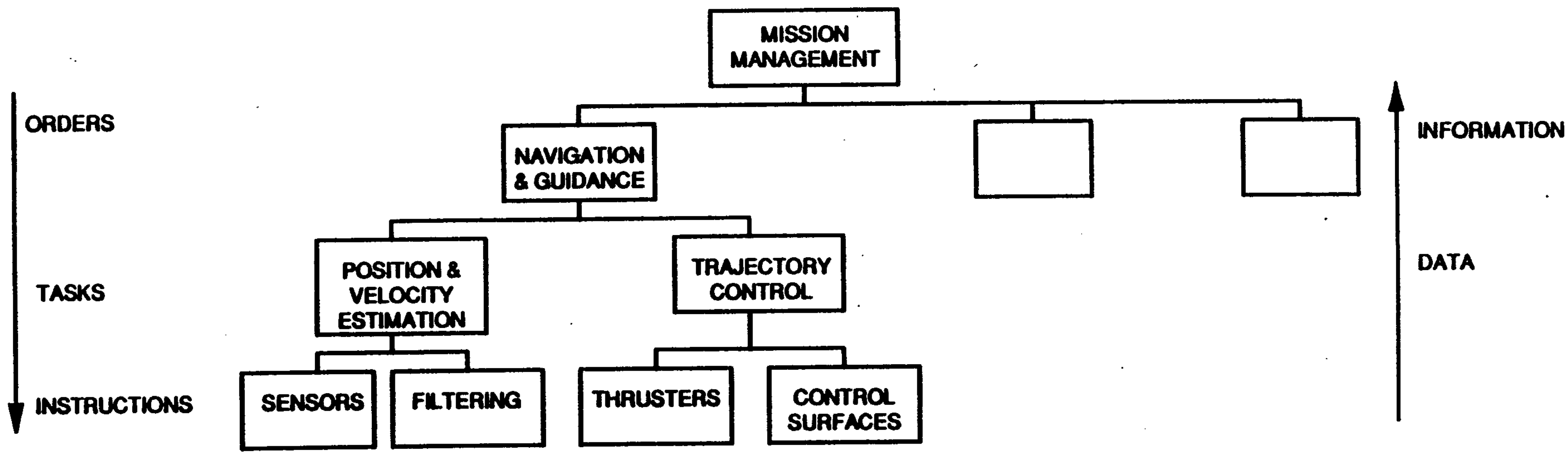

Fig. 6 Typical Hierarchical Architecture

not affect vehicle size, weight or sub-system arrangement and they can be thoroughly investigated by simulation.

A number of studies have concluded that computer hardware is sufficiently advanced for AUVs to be entirely feasible, although software design methods have not kept pace. There is no simple solution to the problem of achieving high reliability in software, a major component in the overall reliability of the vehicle. Disciplined design methods, and use of appropriate development and validation tools will be essential.

DYNAMIC CONTROL

The dynamics of small subsea vehicles are in general both complex and poorly known, which makes the design of stable and reliable automatic control systems difficult. There are a number of ways of tackling this uncertainty. In principle, a system which can monitor the vehicle velocity and attitude and adjust itself so as to ensure accurate and stable control under varying conditions (i.e. adaptive control) is ideal. But, although a large body of theory exists and adaptive controllers have often been simulated, working systems are few and the methods tend to be both complex and untried for subsea vehicle control.

On the other hand the methods of sliding control (Yoerger and Slotine) have been used for subsea vehicles both in simulation and in prototype trials. These methods are attractive in that they provide a stable and predictable system despite uncertainties in hydrodynamic forces and external disturbances.

Simple classical controllers are fairly robust to model uncertainty and if coupling between different vehicle motions is slight it might be possible to control DOLPHIN and DOGGIE using independent control loops, for heading/lateral position and for pitch/height, respectively. Roll control will be required if there is significant torque reaction from the propeller. Requirements for sensor stability are likely to have a greater impact on the control of DOGGIE than on DOLPHIN in this respect. Speed control is desirable for two reasons: there is an optimum speed which minimizes power consumption, and if the vehicles fly at constant speed the need for gain scheduling (and controller complexity) is reduced.

In considering the problem of replacing the man in the control loop two extreme case solutions can be envisaged: we might try to emulate all the adaptability and learning power of the human brain, or alternatively, try to ensure that the vehicle dynamics are entirely predictable at all times (flight control) and that all possible events and combinations of events are anticipated and the optimum responses pre-programmed (mission management).

The Phase I studies of mission and flight control concluded that neither of these extremes is feasible and that the strategy should be:

- to make vehicle dynamics as simple and predictable as possible by careful attention to vehicle design and by ensuring that vehicle geometry, hydrodynamics and mass and volume distributions are not subject to significant changes during operations

- to provide a measure of adaptability/robustness by suitable selection of flight control system type and methods of design

- to determine as far as possible all the events and combinations of events which the vehicle is likely to encounter

- to ensure that evolution of the ability to respond optimally to unforeseen events is restricted as little as possible by the choice of system architecture, design methods and software tools.

Vehicle design, flight control and mission management are closely related and further work will be directed towards a system simulation and development environment. This will be used to explore control strategies, to determine the requirements for hydrodynamic testing and ultimately to develop and test the entire control system.

NAVIGATION

The navigation of DOLPHIN is considered to be straightforward because the required precision is relatively low (within ±2 km of nominal track). The vehicle will have access to the GPS system at frequent intervals and can rely on dead reckoning between fixes using some form of water-referenced velocity log and a fluxgate compass. For DOGGIE the requirements for precision in navigation are much higher and the difficulties in meeting these are severe. The matching of sidescan survey images between adjacent swaths requires a relative navigation accuracy of ~100 m throughout the 50 km x 50 km survey area and this has to be maintained regardless of the topography over which the vehicle passes. The difficulties stem both from the length of time spent submerged - which demands very low drift rates in the navigation system - and from the restricted space and power available in the vehicle for instrumentation, which precludes the use of large and relatively stable inertial systems. The solution presently envisaged (Babb, 1990) would rely on the use of a bottom-locked doppler navigator and a gyro-derived heading reference, which would be used to navigate between a network of moored transponders, giving sparse coverage of the survey box, deployed and surveyed in prior to the mission. The use of transponders is not without difficulty, however. At depths below about 2000 metres the vertical gradient of sound velocity causes upward acoustic refraction and will limit horizontal acoustic propagation for a DOGGIE vehicle cruising at 500 metres altitude to about 15 km. Placing the transponders higher in the water column can increase this range but means of monitoring positional changes due to mooring motion have then to be devised, thereby incurring considerable complexity in the system. In rugged terrain acoustic shadowing is likely to occur if a transponder system is used. An alternative way forward is to develop navigational techniques based on terrain feature recognition, but this is unlikely to prove feasible for a long time yet.

THE WAY AHEAD

A number of uncertainties and technological constraints have thus emerged from the Phase 1 studies. None however suggests that autonomous vehicles able to conduct measurements useful to science cannot be produced within the next few years For the long range DOLPHIN vehicle the primary limitation identified arises from the present lack of a suitable energy source, while for the DOGGIE vehicle navigation and control and mission management in rugged terrain are probably the overriding constraints in the longer term.

Development of a range of subsystem technologies - which vary in difficulty and time needed for full implementation - represents the major task for Phase II of the project (fig. 7). In view of the nature of these tasks the future strategy will seek to minimize risk by adopting a staged approach. Thus the work during Phase II will concentrate initially on producing subsystem demonstrators so as to provide proof of feasibility in the basic vehicle subsystems (Table 2(a)). Work will also begin on the longer term problems that are crucial to the success of the full DOLPHIN and DOGGIE missions (Table 2(b)). Technologies proven in Phase II will form the basis for a demonstrator vehicle to be constructed in Phase III.

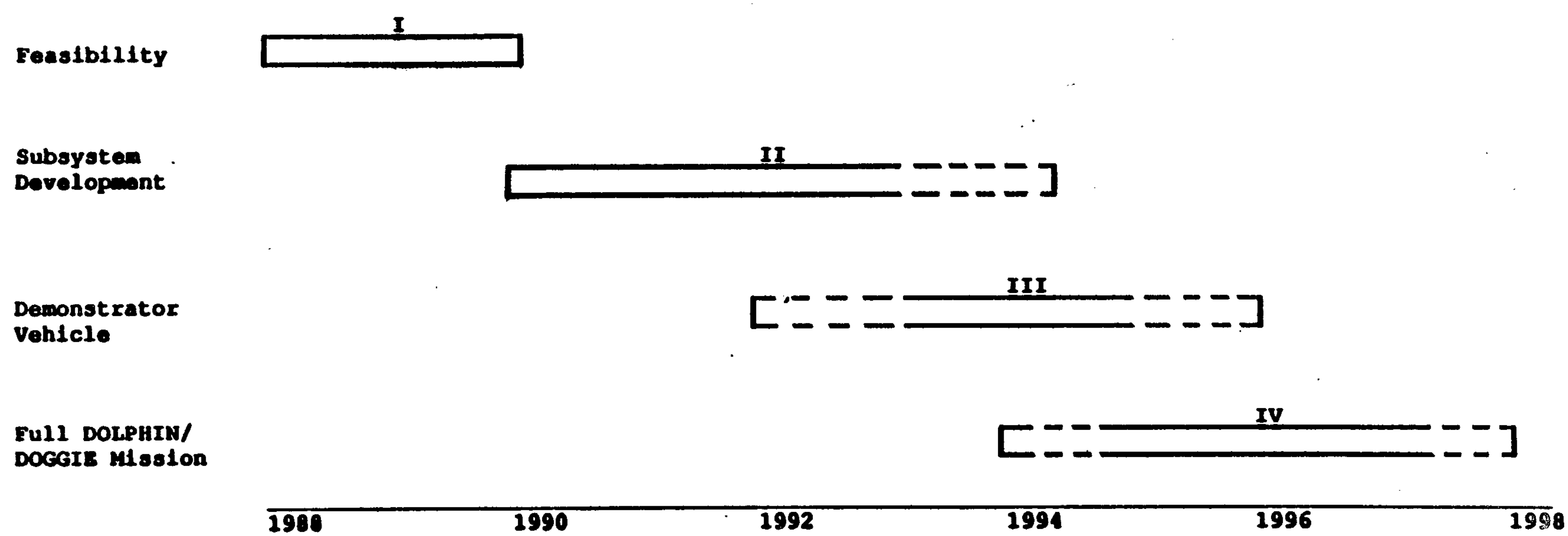

Fig. 7 Project Timescale

TABLE 2: AREAS FOR SUBSYSTEM DEVELOPMENT

(a) Required for Phase III (demonstrator vehicle)

- Full depth pressure vessel using advanced composites
- Vehicle dynamics and control: simulation and model verification
- Vehicle buoyancy and trim control
- Propulsion system: torque-balanced motor and efficient propulsor
- Mission management: simulation and implementation
- Energy source, distribution and control
- GPS position fixing/satellite telemetry link tests
- Deployment/retrieval and logistics

(b) Required for Phase IV (Full DOLPHIN/DOGGIE concept)

- Trials at sea of low-drag hull
- Packaged and validated energy source (fuel cell)
- Comprehensive collision avoidance system
- Accurate local area navigation in complex terrain
- Mission management system with extended reasoning capacity
- Sensor suite design and validation

The primary reason for building a prototype vehicle is to achieve and to demonstrate full autonomy in the context of a relatively straightforward science mission. But it is important, also, that at this stage means should be provided for gaining practical experience, for scientists and technologists alike, in all aspects of the operation of AUVs. In this way a sound basis will be provided for the development of vehicles capable of undertaking the full complexities of the DOLPHIN and DOGGIE missions.

ACKNOWLEDGEMENTS

The Autosub project seeks to involve relevant experience in the wider UK science and technology community. Acknowledgement is made in respect of the contributions to Phase I of the project made by research groups at:

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Brunel University
Courtaulds Ltd (Advanced Materials Group)
Heriot-Watt University
University of Manchester (PREST)
University of Surrey
University College, London
YARD Ltd;

also by the NERC Research Vessel Services and by members of the core team at IOSDL.

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An Automatic, Remote-controlled Measuring and Sampling System for Environmental Monitoring

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Introduction

The increasing threat posed by anthropogenic contaminants to European coastal waters in the last few years, has resulted in an heightened environmental awareness of the European population. There are countless well known pollutants, in the forefront of which are the chlorinated hydrocarbons, the heavy metals and nutrient salts. However, large gaps exist in our understanding and knowledge of the transport, the conversion and breakdown processes of these pollutant substances on their paths to and finally in the sea.

It is, as yet, difficult for scientists and the appropriate authorities to offer any conclusive and convincing evidence as to the origins of environmental disasters. This is, not least, due to the complexity of the interactions of the causitive substances with their environments. Large gaps of knowledge are especially due to the fact that many contaminants can be both present in solution as well as particle-bound. Neither the transport of suspended matter nor chemical-biological exchange and transformation processes can as yet be computed in a realistic way by numerical models. Results from field experiments indicate that, for an improved assessement of the fluctuating contaminant inputs from rivers into coastal waters, a more specific sampling management must be performed in the future. This should include sampling in dependence of relevant hydrographic and chemical/biological parameters. Investigations from mobile carriers such as ships or helicopters must be supplemented by sampling and automatic analyses from stationary platforms (piles or buoys) located in those sensitive areas of significance in contaminant transport. Automatic event-controlled measurements and sampling from such platforms in a closely spaced time grid are the prerequisite in an assessment of the effects that will be caused by future measures of contaminant input reduction. Only continuous time series measurements of contaminant concentrations will allow a statistically accurate evaluation of trends.

The development of suitable marine monitoring networks requires prior development of suitable monitoring stations. In the past, numerous automatic measurement and monitoring bouys have been conceptualised. However, until now efforts to introduce such systems have failed, primarily due to four reasons:

1. the inavailability of sensors or automatic analysers for contaminant concentrations and chemically or biologically relevant parameters
2. the lack of "intelligent" data reduction methods on the station prior to transmission
3. the lack of control of automatic measurements (i.e.no two-way telemetry),
4. the inflexibility of system configurations in hardware and software.

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These difficulties will be overcome by the development of a new system designed in accordance with recent technological developments. Sensors and analytical methods, as yet not available, but necessary for the realisation of an automatic station for contaminant monitoring will be developed within the framework of the project EUROMAR. This applies to such methods which seem to be suitable for an unattended automatic operation on platforms such as analysers for nutrients and chlorophyll. Systems for the automatic measurement of contaminants such as heavy metals and organic micropollutants are as yet so far from realisation that for these substances automatic sampling systems for long-term operation must be developed. The MERMAID (*Marine Environmental Remote-controlled Measuring And Integrated Detection)* -system, presented below is an approach for complete automatic environmental monitoring system.

Scientific institutions[4], and industrial partners[5], together with a Norwegian partner[6], coordinated by the *GKSS Forschungszentrum Geesthacht GmbH* started 1988 the *MERMAID*-project within the frame of EUREKA / EUROMAR. The knowledge and practical experience of manufacturing and operating buoy systems for marine monitoring was introduced by *OCEANOR.*

Operational Principle

The operational principle of the *MERMAID* -concept is depicted in fig.1.

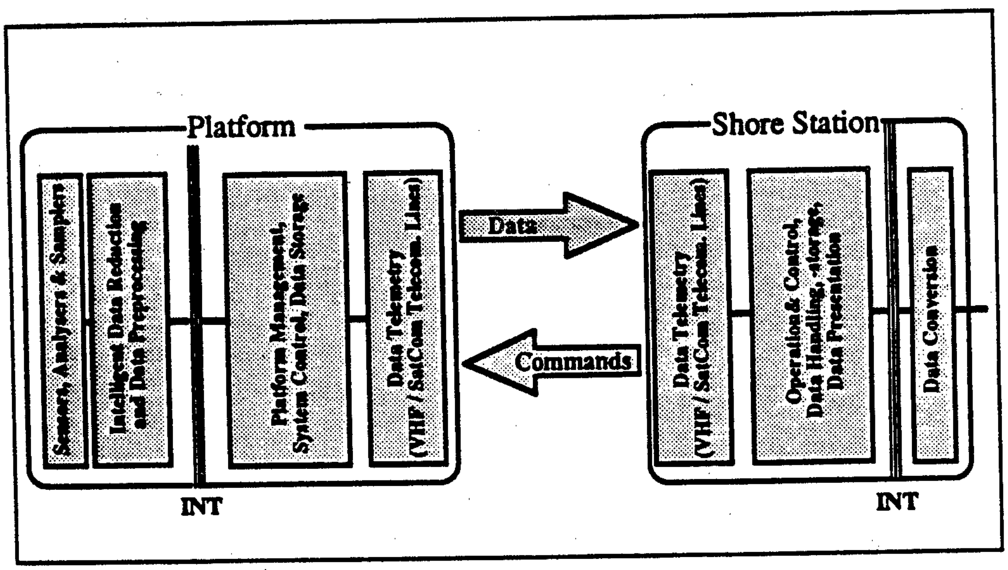

Fig. 1: ***MERMAID*** **Operational Principle**

The system consists of several units located on a sea-based platform (buoy or pile). Data from different sensors or analysers are pre-processed. The quality of

4) Forschungszentrum, Jülich; Deutsches Hydrographisches Institut, Hamburg; Alfred Wegener Institut, Bremerhaven, GKSS Forschungszentrum, Geesthacht

5) Krupp Atlas Elektronik Bremen; Salzgitter Elektronik, Flintbek; Preussag AG, Hannover; Meerestechnik+ Elektronik, Trappenkamp

data is thus improved and the amount of data is reduced. A central platform computer manages and controls all systems and takes care of intermediate storage of data. The operation of pre-processing and management systems can be controlled by commands from the mainland which are transmitted via telemetry (VHF or satellite communication). The data transfer from the platform to the shore is also initiated by commands from the mainland. The land-based systems, situated in the office of the user, permit either automatic operation of the system or in addition manual control. The central *"Shore Management System"* (SMS) offers facilities for data presentation, data storage and -retrieval. To allow more complex data processing such as statistical analyses the data will be converted to a standard format and will be distributed to other users in GKSS,via Ethernet. In the future the data will also be collected from users outside GKSS by a modem.

Although the data are exchanged within the system in a specific format, there are two standard interfaces with the "outside world"(marked with INT in fig. 1). The first is the interface beween the preprocessing and the platform management . Thus, any future commercial sensors can be "customised" to act as intelligent sensor systems. The specific adaption is carried out with a simple 8-bit microprocessor. The standard protocoll of the interface will follow the EUROMAR guidelines, elaborated in the EUROMAR project *FIESTA*.

The second standard interface is provided for data exchange between the shore management station and other mainframe computers.

System Configuration

In fig. 2 the system configuration of the *MERMAID* -system is depicted.

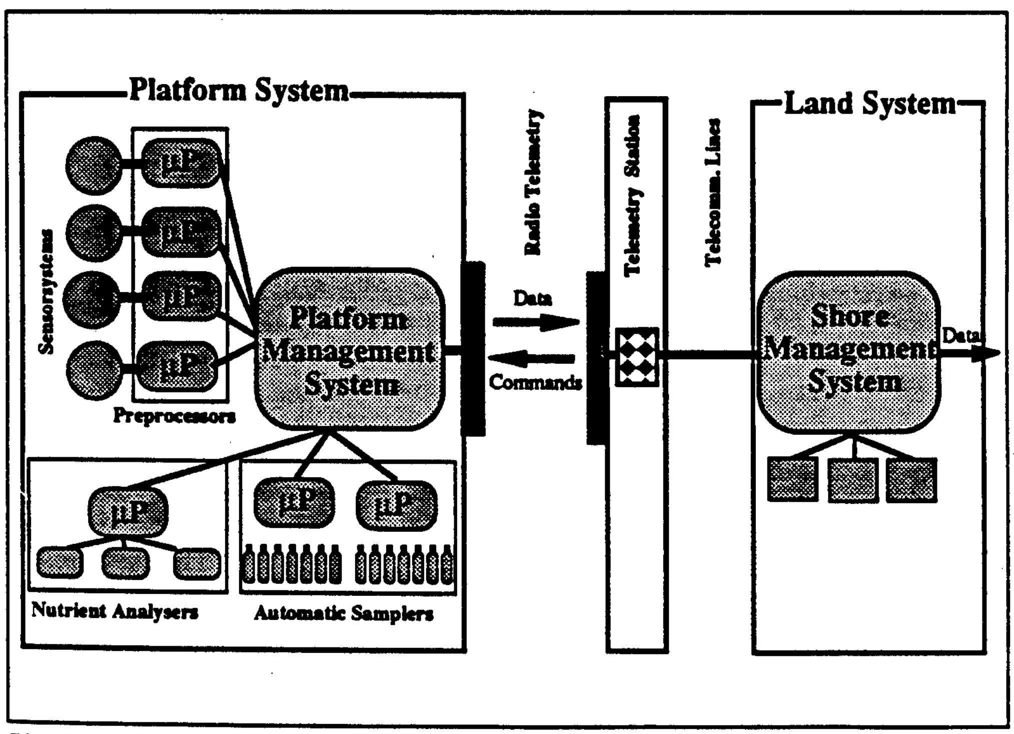

Fig. 2: *MERMAID* System Configuration

The platform system consists of several pre-processing units (**PPSS**), a central *Platform Management System* (**PMS**) , intelligent sampling systems and nutrient analysers. Data and commands are transmitted via two-way radio telemetry to a telemetry station on shore. Communication with the *Shore Management System* (SMS) is provided via telecommunication lines.

Fig. 3 gives a close up view of the platform systems.

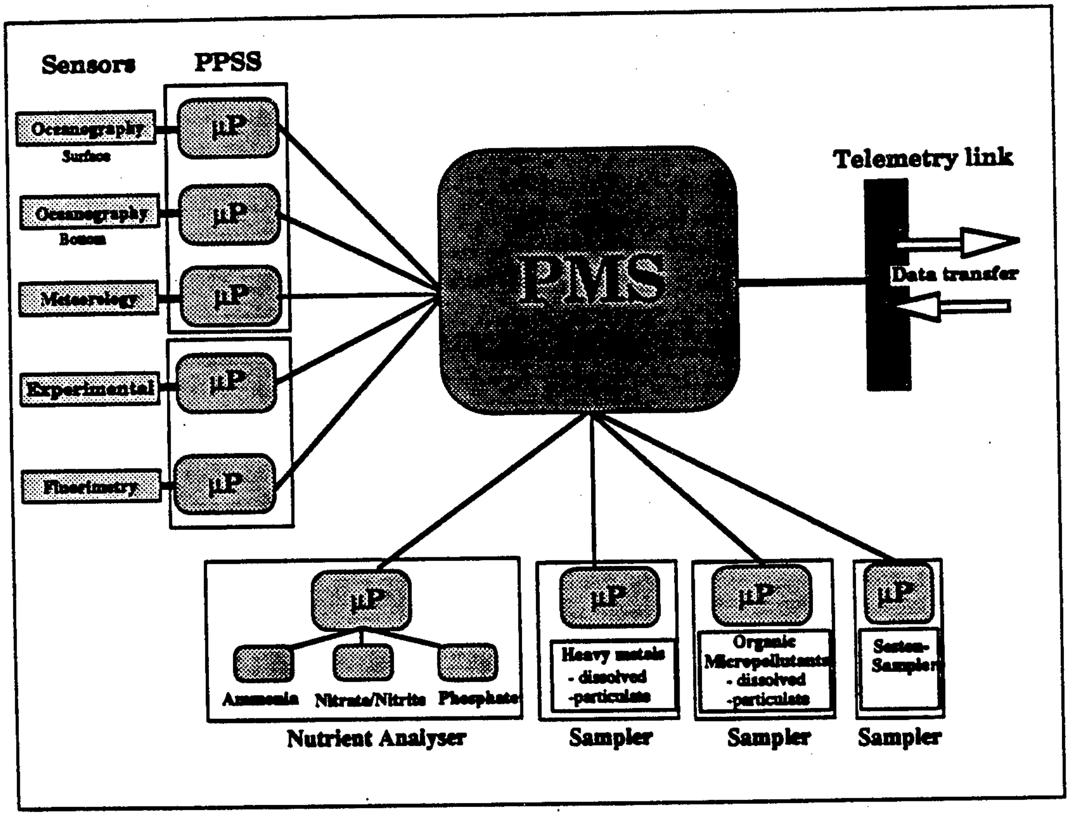

Fig. 3: *MERMAID* Platform Systems

Four different sensor systems, coupled to pre-processors, are being developed in phase I of the project; a fifth PPSS for a special fluorimetrical sensor is planned. There are two sensor systems for oceanographical parameters; one situated near the surface, another near the seafloor. The PPSS for meteorological sensors processes "housekeeping" data as well (electrical powersupply etc.). Another PPSS is provided for the connection of sensors used in the testing of accuracy and long-term stability in future.

Three automatic nutrient analysers for ammonia, nitrite/nitrate and for phosphate are controlled by another microprocessor.

A microprocessor-controlled sampler for heavy metals, coupled directly to the PMS, is developed in phase I of the project; samplers for organic micropollutants and a *Seston Recorder* ™ will be connected later.

Description of Modules

Sensors

The oceanographical sensors applied in phase I are listed in the following table:

Parameter	Function	Range	Manufacturer
water temperature	Pt-100	-5.00...50.00 °C	Salzgitter Elektronik
conductivity	inductive	1.00...30.00 mmho	Salzgitter Elektronik
current velocity	acoustic	0.03...2.00 m/s	Meerestechnik Elektronik
turbidity (2 cm path)	optic. attenuation 650 nm	≈ 3-500 mg/l susp. matter	Hydrobios
turbidity (4 cm path)	optic. attenuation 650 nm	≈ 0.5-200 mg/l " "	Hydrobios
water depth-surface sensor	acoustic (echosounder)	1.0-50.0 m	Metrotek
water depth-bottom sensor	pressure sensor	1.00-30.00 m	Natec
oxygen	Clark sensor	1...200 % saturation	Meerestechnik Elektronik

The meteorological sensors used in the project are standard sensors for windspeed, wind direction and air temperature.

Preprocessors (PPSS)

Hardware
The preprocessors were developed by *Salzgitter Elektronik* for oceanographical applications under water up to a depth of 7000 m. Processor (Z80) and all other modules are located on circular printed boards, assembled as a "tower" and situated either in pressure-tight housing or as a 19"plug-in module. The consistent employment of CMOS technology ensures low energy consumption. Each PPSS can be assembled according to the specific requirements of the connected sensors either with software-controlled pre-amplifiers, multiplexers and A/D converters (12- or 16 bit) or with parallel / serial digital interfaces .
The PPSS comunicate with the PMS via a serial interface (RS232). A second identical interface can be used for service purposes.

Software
The first step in data processing after the digitizing of analog signals consists of optional noise reduction. If in a data stream one or more digitized values are outside a selectable error limit they are marked. In the following software steps these marked values can be processed differently from the other data (e.g. excluded from averaging, spike elimination). The error limits are adjusted dynamically according to the time constants of the sensors. Eliminated values are transmitted for quality control.

Subsequent steps in data processing comprise averaging routines (1 s ...1 h) and the conversion of raw data to "physical" data (SI units).
All described steps, including the choice of different conversion algorithms, can be controlled from the SMS (via PMS).

The preprocessors provide several test facilities which can also be remotely activated. The user-access is limited to raw data display for checking the sensor performance. Qualified service personnel has additional access to several testing tools (remote diagnosis).

Platform Management Station (PMS) and Shore Management Station (SMS)

PMS

The PMS performs the central management tasks of the station. It consists of a microprocessor system (68020, VME bus) with a realtime operating system OS 9. The PMS communicates with the PPSS's, analysers and samplers via RS232 interfaces. The binary communication protocoll provides handshake sequences and error checks. All program sequences were written in the C language for compatibility reasons. Since a mainly experimental system is developed in phase I of the project, a Winchester disc is provided for intermediate data storage on the platform (in future systems the disc will be exchanged for a silicon memory).

The PMS software, developed by *Krupp Atlas Elektronik* , provides automatic control of all peripherial microprocessors (e.g. hardware or software reset) whereas the PMS itself is controlled by a *watch dog* circuit.

One important feature of the PMS software is the automatic activation of samplers and analysers in dependence of hydrographic "events". The conditions which trigger a sampler/analyser are derived from a combination of parameters originating from oceanographic and other sensors. They are generated by the user on the SMS and may be altered at any time.

SMS

The SMS is the "human interface" of the measuring system. An 32 bit computer (Intel SYP 302 with 80386 CPU, 25 Mhz, 16 MB RAM, 600 MB disc) was chosen for this purpose. Since many tasks have to be performed simultanaeously (i.e. data transmission, data storage, data presentation) UNIX was chosen as operating system (SCO UNIX V/386™). The graphical user interface uses an *X Window System* (SCO Xsight™) for OSF/Motif™ .

The program development is being performed by *Krupp Atlas Elektronik* and *GKSS*, using a modern software development tool (Excelerator from AiD).With this tool the software development is carried out by *design by iteration*, but the system description is top-down (*stepwise refinement*).

The structure of the user interface is menu/mouse-oriented and follows mainly the *Human Interface Guidelines* from Apple (*See-and-point* instead of *remember-and-type*). It permits the user to perform all necessary tasks (i.e. set-up, control functions, presentation functions) with a minimum of effort.

On-line or off-line data may either be presented in alphanumerical or in graphical form on the screen, on printer or plotter. The system also takes care of automatic data transmission from the platform at selected times.

The SMS is coupled to the *GKSSnet* via *TCP/IP* for further complex data processing on mainframe computers.

Telemetry

Since during phase I of the project the distance between platform station (buoy) and shore is less than 5 km, a radio telemetry in the VHF band (160 Mhz) was chosen (For future offshore applications a satellite communication system will be provided). The principle of data communication is depicted in fig.4.

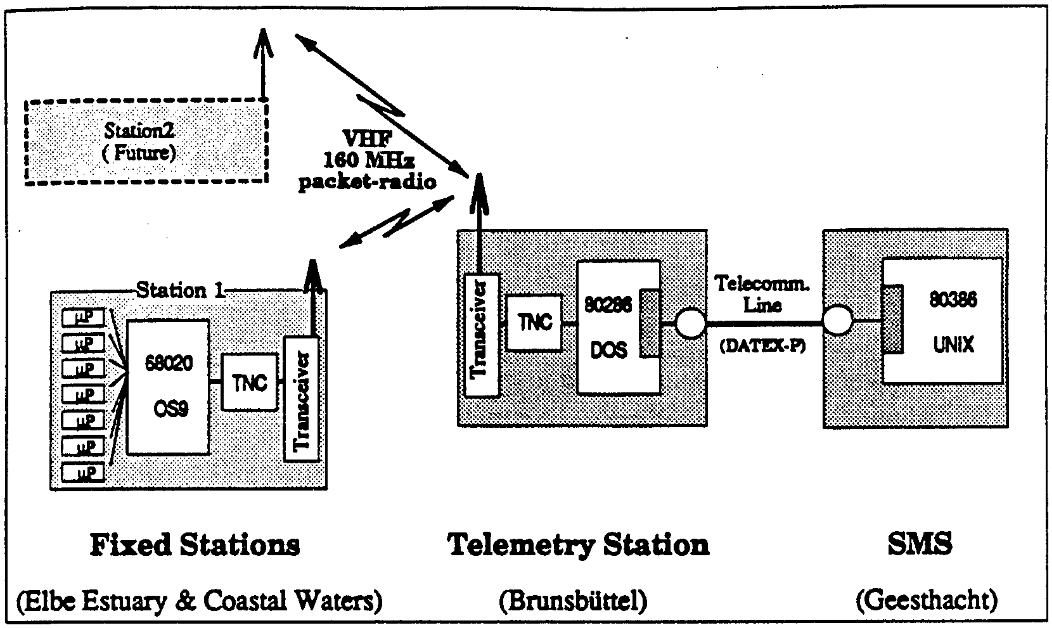

Fig. 4: Data Communication

The radio telemetry system consists of two commercial transceivers (Telecar 9 from AEG) controlled and modulated by *terminal node controllers* (TNC) which communicate via a RS 232 interface with the PMS on the platform and a small PC at the telemetry station on shore. The microprocessor-based TNC's provide the flexible connection with several stations using a modified X.25 protocoll. The datastream is cut into small packets of 128-1024 bytes with an additional address. The reception of the packets must be acknowledged by the other station or the transmission is repeated. A net data rate of 1000 to 2000 characters per second can be achieved (depending on the occurring radio interference on the radio channel). Since an error check is performed on each packet and the communication protocoll of PMS-SMS provides an additional error check, an error rate of $1:10^8$ can be expected.
In Germany regulations of the postal authorities do not allow a direct connection of the TNC with official telecommunication lines. Therefore a small IBM-compatible PC with transparent communication software is used. The data are transmitted via telecommunication lines in packets of 128 byte (X.25 protocol, DATEX-P). The necessary interfaces at the telemetry station and at the SMS are SICC X.25 plug-in cards (Stollmann).

Sampler for Heavy Metals

The main objective of the *MERMAID*-system is the assessment of water quality by the measurement of contaminants. Since at the moment automatic analysers for heavy metals or organic micropollutants are not available and, due to the complexity of trace analyses, will not be available in the near future, automatic sampling systems have to be used. In phase I of the project a functional model of a heavy metal sampler will be developed by Preussag Meerestechnik, Hannover. In order to prevent transition of heavy metals from the *particle-bound* into the *dissolved* phase and vice versa the samples must be filtered immediately. Filter and fitrate must be preserved and stored separately for analysis in the laboratory. Special care concerning errors caused by contamination must be taken.

In fig 5 a scheme of the automatic heavy metal sampler is depicted. During sampling, water is sucked in by a contaminant-free pump. In dependence of the actual concentration of particulate matter, measured by a turbidity sensor, a well-defined water volume is taken by means of a metering pump. The sample is tranferred via a filling head into one of 24 cylindrical filtration vessels, the bottom of which contain 0.45μm Nucleopore filters. The sample is filtered by the application of pressure (nitrogen, 2 Bar) into a 500 ml PE bottle, which is fixed underneath the vessel. For preservation purposes the bottle contains 200μl of ultrapure nitric acid. Afterwards the filter is preserved by 75 μl of a preserving reagent. The whole operational sequence including flushing and rinsing is described in fig.5.

The operation of the sampler is controlled by a 6809 microprocessor; communication with the PMS is carried out via a serial interface using the binary standard protocol. Sampling is initiated by the PMS, a complete sampling report (no. of bottle, filtration volume, filtration time, turbidity etc.) is stored and and transmitted to the PMS.

An unattended operation of 30 days is envisaged. During this time 24 samples, can be taken.

Nutrient Analysers

Automatic nutrient analysers for the determination of nitrate, nitrite, ammonia and phosphate, which are suitable for operation on small platforms (Automatic Pumping Photometer, **APP** ™, Meerestechnik Elektronik, Trappenkamp), already exist. These analysers are being modified for unattended long-term application.

Fig. 6 shows the measuring principle of an APP with filtration unit.

The main part of the discontinuous operating analyser is the pumping photometer, a combination of a syringe-type pump and photometer. The nutrients are determined in accordance with oceanographic standard procedures by reactions forming coloured compounds, the optical absorbance of which are measured photometrically. Mixing of sample and reagents is carried out in a mixing chamber. Monochromatic light for each nutrient to be analysed is generated either by a light emitting diode (LED) or a tungsten lamp with interference filter. The analytical procedure is controlled by a microcontroller. Parameters such as cuvette length (= length of optical path), dilution of sample, reaction time etc. can be selected.

A filtration unit is provided for coastal areas and estuaries with large concentrations of particulate matter. After an analytical cycle the filter can be cleaned and preserved in order to prevent bacterial growth.

Three analysers (ammonia, nitrite/nitrate, phosphate) are controlled by a 80 286 microprocessor which itself communicates with the PMS (RS232, standard protocol).

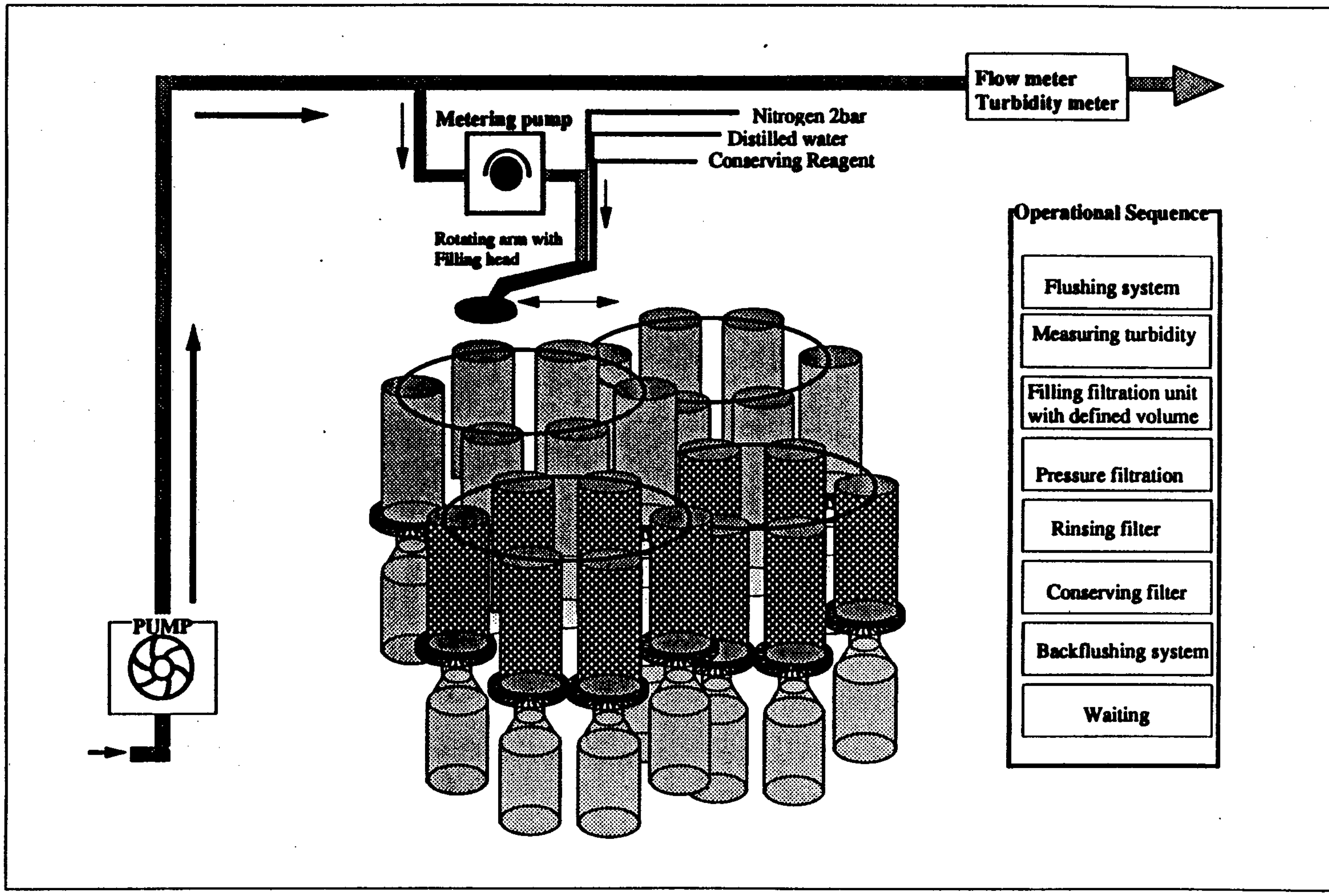

Fig. 5: Principle of the sampler for heavy metals (AISIT)
(Automatic Intelligent Sampler for Inorganic Trace Compounds)

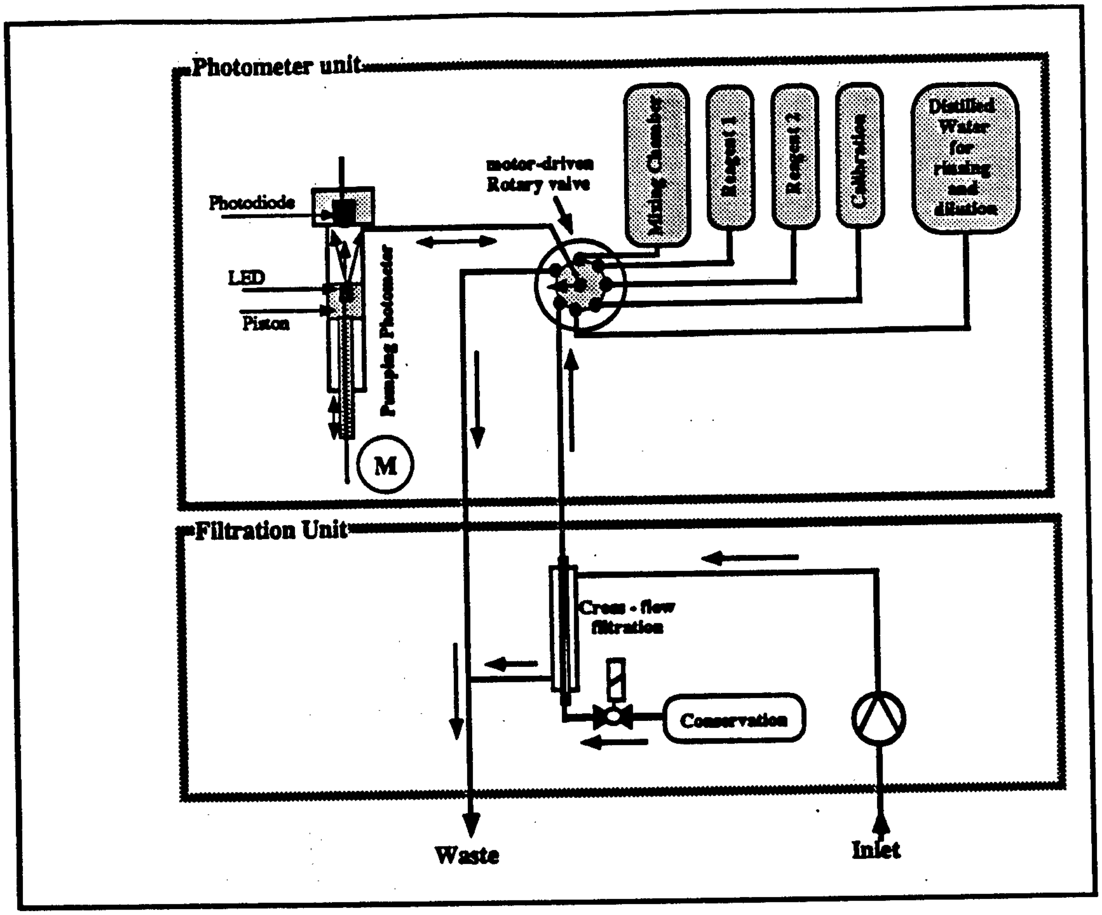

Fig. 6: Principle of the Nutrient analyser

The Carrier System

The hardware modules described above can be installed on nearly any platform as carrier system such as buoys, piles, lightships or oil riggs. At first the system will be established as an experimental setup on the GKSS buoy *META-1* (Marine Experimentier-, Test- und Arbeitsboje). This is a large discoid buoy similiar to the *Lanby* (Large Navigational buoy) type developed by the British factory Hawker Siddeley Dynamics. It was constructed in 1975 within the framework of the VEMNO program (Vorentwicklung Meßnetz Nordsee/Ostsee).

The body of the buoy has the function of a wave-follower and is therfor flat-bottomed. The underwater unit consists of a flat frustrum on which a cylinder of 12.4 m diameter is mounted. The body of the buoy is devided into five water tight compartments and two tanks used for fuel and ballast. The square central room is 4.8 mx 4.6 m wide and has a height of 1.6 m. A conical deckhouse on the buoy has a diameter of about 4 m.

The buoy is equipped with a central moon-pool of 70 cm diameter. It is here, where the oceanographical surface sensors and the water inlets for the sampler and analyser are located.

Other oceanographical sensors are fixed together with an underwater preprocessor on an underwater frame which is located to one side, under the buoy, on the sediment.

The buoy is equipped with a silicon solar panel of about 12 m^2 connected to rechargeable lead batteries with a capacity of 300 Ah. The mean power (24 hrs, between March and October) is 200-300 W at 24V. A diesel generator (8 kVA) with auto-charge facilities for the batteries provides additional energy for experiments. Winches are powered by a second diesel generator (23 kVA).

Application of the *MERMAID* - system

The different modules of the *MERMAID* - system can be assembled together to a system, customized according to the requirements of the specific task to be performed. A small buoy with only few oceanographical or meteorological sensors and a limited power supply would, as example, consist of only one preprocessor which takes over some of the control tasks which in larger systems are performed by the PMS. The advantage for this solution is, that this buoy may be integrated into bigger systems and that all software for operation and data presentation on the SMS is available.

The use of a large system, containing samplers and analysers, for water quality control shall be demonstrated in a typical scenario:

The assessment of contaminant transport from rivers into coastal waters can be improved by the installation of an measuring platform in a sensitive area (i.e. the outer estuary). In order to get samples (e.g. for particle-bound heavy metals) which are representative for the material transported into the sea, sampling has to be performed shortly after the slackwater point ebb-tide, when much of the coarse material has already settled. By using the flexible software provided by the *MERMAID* -system the exact slackwater time can be determined. Over and above that it is possible to react to other events such as large freshwater input from upstream by taking additional samples.

Acknowledgement

The German part of the *MERMAID* - project is financed under the umbrella of *EUREKA* by the German *Ministry of Research and Technology* (BMFT).

OCEANOLOGY INTERNATIONAL '90

March 8, 1990, Brighton

Opening address by Prof. Olaf MEYER
Head of the International EUREKA SECRETARIAT, Brussels

The EUREKA Initiative for International Technological Cooperation in Europe

Introduction

With production costs decreasing, R&D costs increasing, production preparation costs rocketing and pay back periods shortening in the hi-tec race, more and more firms and research institutions need to collaborate to remain leading innovators or to strike up strategic alliances.

It is against this backcloth that the EUREKA Initiative has been started and is working. Its aim is to strengthen Europe's industrial and technological competitiveness in civilian high technology areas where inter-company collaboration, possibly coupled with actions to secure greater integration of the European market, will establish a leading edge.

Involving 19 European countries and the EC Commission, EUREKA is a mechanism providing industries and research institutions with an opportunity to develop advanced technology products, processes or services on a collaborative basis.

EUREKA is primarily directed at the commercial exploitation of the projects being industry led and market driven - and complements in so doing the EC or national R&D programmes, that usually are focused on projects well upstream from the market place.

Results So Far

Presently, some 300 projects with some 1.600 participants and a total budget of some 6.500 MECU are in progress.

Table 1:

PARTICIPATION BY COUNTRY (Oct. '89)

Austria	38	Italy	88
Belgium	36	Luxembourg	5
CEC	4	Netherlands	73
Denmark	35	Norway	34
Finland	30	Portugal	21
France	135	Spain	86
F.R. Germany	107	Sweden	51
Greece	15	Switzerland	35
Iceland	3	Turkey	3
Ireland	9	U.K.	88

As one would expect, the participation by country follows roughly their respective economic size. Also one observes that there are participants from 3 countries in the "average project", demonstrating that many projects are truly multinational rather than bi-lateral.

Table 2:

PROJECTS BY TECHNOLOGICAL AREA (Oct. '89)

AREA	NO. OF PROJECTS	TOTAL ESTIMATED COST (MECU)	TOTAL NO. OF PARTICIPATING ORGANIZATIONS
BIOTECHNOLOGY	55	540	192
COMMUNICATION	19	1190	145
ENERGY	14	520	70
ENVIRONMENT	32	600	347
INFORMATION	50	1500	199
LASER	13	270	167
MATERIAL	23	150	106
ROBOTICS	70	1150	416
TRANSPORT	21	590	94

*) Including double counting of organizations

The EUREKA Initiative does not limit the projects to any limited technological area, but welcomes project proposals from all civilian high technology fields. For statistical purposes, the projects are then grouped into the "technological areas" as per Table 2. This table shows, that there are some remarkable differences in the number of participants per "average project": mostly, one finds 4 to 6 as an average, but as many as 11 are found to participate in the average project of the "Environmental Field". It is just in this area, where you also would find the oceanology projects of environmental importance, as e.g. EUROMAR, which will be presented separately later today.

EUROMAR represents a type of project of special significance to EUREKA. On one hand, it is truly multinational, which obviously must be regarded as highly beneficial in view of the internationality of the marine environment. On the other hand, it is also a so-called "umbrella" project, i.e. a project organized in such a way that new sub-projects are generated continuously and that ongoing sub-projects are supported and protected.

The Benefit to the Participant

To the surprise of many, there is no international funding provided by EUREKA - EUREKA is simply not any sort of financing scheme. So, why should one choose to run a cross border cooperation project under the "EUREKA flag"?

* Partner Search

EUREKA's administrative bodies are available for active partner search - regardless whether early in the proposal phase of the project when maybe only one single participant and his idea exist, or later in the project when added competence is required for any reason (further one market to be covered, further one technological still needed, a not performing participant to be exchanged etc.).

* Legitimacy

There are famous, well known and often discussed hindrances to collaboration. They even have nick names as e.g. "NIH", the "Not Invented Here" syndrom or "David-Goliath", the notion of the powerful large company robbing the single inventor of his brilliant idea, maybe also the opposite, namely the notion of the crazy inventor harrassing the large company.

Experience has now very clearly shown that cooperation projects within EUREKA give legitimacy to the project in a most distinct manner and thereby gives legitimacy to the participants in their project relation. Cooperation develops consequently in a very much more pragmatic way with less mental tensions than one otherwise observes in cooperative attempts.

* Public Funding

As said above, there are no international public funds for EUREKA projects, but, surely, on a national basis the national part of any EUREKA project can be a candidate for national public funding. Such funding would always have to follow national rules, preferences, policies, schemes and procedures - and they are obviously not equal from country to country. They are not made equal for the sake of EUREKA either, but one observation is actually valid for the public funding or risk financing schemes of all EUREKA member states: there is some sort of priority for EUREKA projects. This might, in one country, be in the form of special "earmarked" EUREKA funds, in the other only as an increase in the speed of application handling, but one always finds some sort of priority or preference.

** Advice/Mediator*

Crossborder cooperation one finds rarely tought as subject at managerial schools, and, consequently the knowledge of this special profession is hardly widespread or profound. Since on the other hand, the success of every project critically depends on its professional management, EUREKA assists with advice and - if need be - as mediator, all of course if the participants so desire and specify. Some checklists or guidelines - e.g. on how to formulate a cooperation contract - are also available.

** Supportive Measures*

In the context of EUREKA, supportive measures are described as the enabling conditions that projects may require for their successul completion, development or introduction on the market.

As many of these conditions may be beyong the scope, capabilities and influence of the individual project, the EUREKA framework can offer an added value in this area, through the possibility of channelling specific requests from individual or grouped projects to appropriate bodies, or, in a broader way, through the endorsement of the requests by the EUREKA responsible bodies.

These general ideas, though somewhat vague, are in practice translated into a number of specific and concrete action fields, namely:

- Standardization
- Regulation, rules
- Public procurement
- Protection of industrial and intellectual property
- Private financing support
- Promotion

This list is by no means limitative, nor are the examples to be understood as an ambitious instrument of a top-down directed approach.

The core of the entire action in this area is dominated and oriented by the specific requests received from the individual or clustered projects. In other words, when a project meets obstacles, which could be resolved by political or governmental action, please let us know and the EUREKA bodies will try to solve the problem.

Oceanology in EUREKA

Sorry to admit, but oceanology has not (yet ?) grown to such a volume, that it has conquered its own technological area within the EUREKA statistics. However, a considerable number of EUREKA projects could undoubtedly be called oceanology projects even if they just now are registered under wider headings, as e.g. the environmental area or in special technological fields as energy, informatics or robotics.

Through its size, the umbrella project EUROMAR with 18 sub-projects (out of which at present 7 with separate budget and EUREKA number), no less than 54 participants from 13 countries, catches the interest. This project will - as said - be presented separately as well as one of its sub-projects, the Mermaid.

Other EUREKA projects with connection to the ocean concentrate on various methods to combat water pollution (as EU 253, HYPRO for sewage treatment or EU 195, RESTORE for silt decontamination), on the development of equipment (as EU 357, APECS for pollution control in very shallow waters or EU 356, MAC, a multipurpose anti-pollution craft) or on the evaluation of installations (as EU 394, WAVE ATTENUATORS, a new concept to decrease coastal erosion due to ocean waves).

The technical area of informatics contains of course many elements of potential interest also to oceanology as indeed it is to almost all areas of mankind's industrial activities. In the area of energy, we find e.g. projects aimed at improving the efficiency and safety of oil/gas well production at sea. Finally, the area of so-called "robotics" does not only include EU 191, the underwater robot for maintenance and surveillance which will be presented later today. We find also an advanced attempt to greatly improve fishing boats and fishing techniques - truly in line with the notion that fishing is a production process that needs "robotisation" as any other process.

The interested reader, who would like to learn more about the content of the EUREKA project portfolio, is cordially invited to send such request to the EUREKA Secretarit, Avenue des Arts 19H, B-1040 Brussels.

Cooperation Pitfalls

EUREKA advocates crossborder collaboration as a tool to achieve high-tech R&D results in a quicker, cheaper and more efficient way than single actions would allow. In certain cases, combined actions might even be considered to be the only way to reach the desired result (e.g. size of operation like JESSI, geographical considerations like in EUROMAR or standards like for HDTV).

The principal advantages of collaborative efforts are also advocated by a number of other initiatives or programmes, both on multinational, bilateral and national basis. Several CEC programmes and national technology transfer programmes might serve as examples.

Whilst the arguments for the benefits of cooperative efforts are put forward with much emphasis and obviously meet with easy understanding - they are actually quite convincing -, arguments regarding the drawbacks of cooperation are more seldom articulated.

There are, however, obvious and serious drawbacks in cooperative activities, which in certain cases could outweigh the benefits. At a recent conference, on "The Cooperation Phenomenon - Prospects for Small Firms and the Small Economies", organized by EOLAS, Ireland, one of the main conclusions drawn by some 80 delegates from all over Europe, including CEC and OECD, was the following:

"It should be the responsibility of every initiative or programme, that advocates cooperative efforts, also to warn for the possible drawbacks of such cooperation and - if possible - to assist their clients in minimizing such drawbacks".

Consequently, some viewpoints on the possible drawbacks of cooperative projects should be offered:

First of all, there must be a good reason why a certain project is to be done in cooperation. It is always cheaper to complete a project alone if one has all the resources necessary to do it alone. This same logic can also be expressed in the rather simple sentence: The partners must need each other - for some good reason. In this, beware of emotional reasons and identify the strong and clear strategic arguments of the company or institute why cooperation on just this project together with just those partners is motivated.

Secondly, one must see to it, that the entire personnel that is supposed to cooperate, is well motivated to do so. Nothing can jeopardize the outcome of a cooperative project more than lack of motivation or understanding for the cooperative effort, how the work is divided and why, how the "glory" will be divided and why etc.

Surely, a solid contract is needed, well elaborated and clear, but not negotiated with "hostile fine print" which might kill all the enthusiasm for the partnership before it actually started. The division of profits and rights has to be included, but the division of all negative factors that might come, must not be forgotten either. Who takes the blame if the prototype explodes and kills three people in the process ? might be a somewhat exaggerated question, but points into the direction.

The above are some arguments worth considering. Experienced companies of course know all this and much more, but the newcomer might be still somewhat astonished when the following is stated:

As in most modern market oriented R&D projects, strategic considerations, sufficient financing as well as good market knowledge and access are far more important than technical details.

Conclusion

The EUREKA model of market oriented, industry-led crossborder cooperation, has very quickly led to a project portfolio of obvious importance. A continued increase in number of projects and volume of the portfolio can be reported as well as the fact that the EUREKA model as such is copied by other initiatives - only this, a sign for success in itself.

The advantages to the participant are clearly considered important, eventhough they do not contain any international funding, and - if only the possible drawbacks of cooperation are avoided by careful strategic planning - crossborder R&D cooperation projects offer the extra advantage that is available in Europe for better, quicker, cheaper and industrially more successful development.

Olaf MEYER
9/02/90.

EUROMAR - A Challenging Opportunity for International Cooperation for Development and Marketing of Marine Environmental Surveillance Technology

by

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Meinhard Schulz-Baldes, General Secretary of EUROMAR, Alfred-Wegener-Institute for Polar and Marine Research, Bremerhaven, FRG

OCEANOR/2548/aks/V2/90.02.15

INTRODUCTION

Men have caught fish in the ocean and extracted salt from its brine for thousands of years, but only within the past decade have they begun to appreciate the full potential of the 350 million cubic miles of ocean water which constitutes the earth's largest continuous ore body.

Modern scientific oceanography is generating new knowledge of what exists in and under the sea. New technology makes it feasible to reach and to extract or harvest natural resources that were previously inaccessible. Although the present level of exploitation of the oceans is growing rapidly, the potential is still enormous.

However, our oceans are threatened by environmental problems. It seems that mankind's unwise use of the sea as a huge dustbin is about to reach the point of no return. This frightening situation has caused a remarkable turnaround and a new willingness to preserve this, the last of Earth's treasures.

In the Europe today, there is increasing acceptance of the need to protect the marine environment - and to use the money and resources this requires.

EUROMAR BACKGROUND

The EUREKA Project EU 37 EUROMAR is entitled:

> *Development, application and successful exploitation of Europe's advanced marine technology having worldwide market potential*

with its following terms of reference:

- foster technology progress for integrated ecological management of the marine environment
- promote cooperation between industry and science in developing marine instrumentation, methods and operational systems
- improve the productivity and competitiveness in European marine industry for worldwide application

EUROMAR started officially at the London Ministerial Conference in June 1986 and has since then been developing well in various areas. Existing projects are making substantial progress, and additional new projects are continuously launched.

As part of EUREKA, the EUROMAR project, in which 13 European countries (including Yugoslavia) and the European Community are involved, acts as a "mother project" in order to give birth to many other projects within EUROMAR's broad area of interest - the ocean. This interest covers a sound knowledge of and insight into the physical, chemical and biological conditions governing the extent and distribution of resources in the seas, and the location, nature and degree of discharges and other influencing factors.

Although it is widely recognized that the world's oceans play a major role in global environmental change, a complete scientific understanding of the interactive processes involved is hampered by the lack of marine data. To really understand the complicated processes of the ocean, and to predict their outcomes over time-scales of months, years or even decades, experts need to observe and describe them in detail.

Sophisticated coupled numerical models of the ocean are vital for predicting marine environmental changes. Satellites can provide some of the global synoptic data needed, particularly from large areas of ocean previously unobserved. But these measurements need to be validated and complemented by reliable in-situ, ground-based, information. This demands that full advantage be taken of all technological advances in sensors, platforms, measuring systems and data telemetry by means of internationally coordinated, cost-effective programs that ensure easy access to the data by all users.

The marine environmental data from the European regional seas, and the pollution monitoring technology available today, are not adequate for making proper evaluations. For example, the need is plainly expressed in studies by the Second International Conference on the Protection of the North Sea and by EUREKA's EUROMAR project to develop new technology for monitoring the marine environment.

EUROMAR ACTIVE PROJECTS

Environmental technology in a broad sense is our one and only tool to remedy the damage already done to the environment and to reduce and prevent further damage. Environmental technology is also one of industry's fastest growing segments and thus presents itself as an area of new business opportunities. In Norway, for example, the Norwegian Parliament has made environmental technology a new target area for national research and development.

What observations are needed? What are the major challenges confronting us?

The market opportunities for industry will be in sensors, communication systems and systems for data reduction, processing, integration and presentation. Data will be collected from shore-based stations, ships, buoys, aircraft and satellites.

EUROMAR is proceeding strongly, with existing projects making good progress and new projects being launched regularly.

Bringing together marine researchers, agencies, designers and industries more than twenty EUROMAR daughter projects have been successfully initiated. These include both marine surveillance systems undertaken for the purpose of combating pollution and more product-oriented projects geared to the industrial development of marine technology in specific fields.

Projects like MERMAID and SEAMOS, for example, will develop remote-controlled monitoring systems in the sea, BIMS a system at the sediment-water interface and ATMOMAR for measuring atmospheric input into the sea. SEASTARS aims at an airborne multi-sensor package. FIESTA will link these projects by selection of interface standards.

CHARISMA, ACOUSTIC CAMERA, ARMS, SEDIFLUX and HYDROFAN will make use of the sound to characterize sediments and suspended matter, while DISC explores the engineering properties of the sea bed.

SMURV will develop an advanced prototype of a flexible multi-purpose research vessel. MOSES aims at the construction of containerized, mobile laboratories and instrumentation. ELANI will design advanced electro-chemical instrumentation, MAROPT an underwater video camera for plankton identification.

ISLE focuses on a comprehensive information system for the local marine environment while MARSIS will offer professional use of remote sensing information.

VISIMAR will create video animation to depict marine environmental processes. OPMOD is developing a computer model which will allow short-term forecasts during accidents like oil spills or chemical spreading.

The total economic commitment in these projects are shown in Fig. 1. Not all of the projects have their funding fully established but the figure nevertheless gives an impressive demonstration of the activities underway.

EUREKA embraces the 12 EC countries, the five EFTA countries, plus Finland and Turkey. It is primarily an industry-led research program, but its scope is all of science and technology. Its emphasis, however, is on how science can improve industrial performance.

EUREKA projects can start with the enthusiasm of a single organization anywhere within the 19 member states. To launch a project this company has only to get the support of one other company, government agency or university from another EUREKA member country.

In this way EUREKA acts as a brokerage for research and development, advising organizations looking for outlets for their research and development capabilities as well as partners to share the cost of developing their ideas.

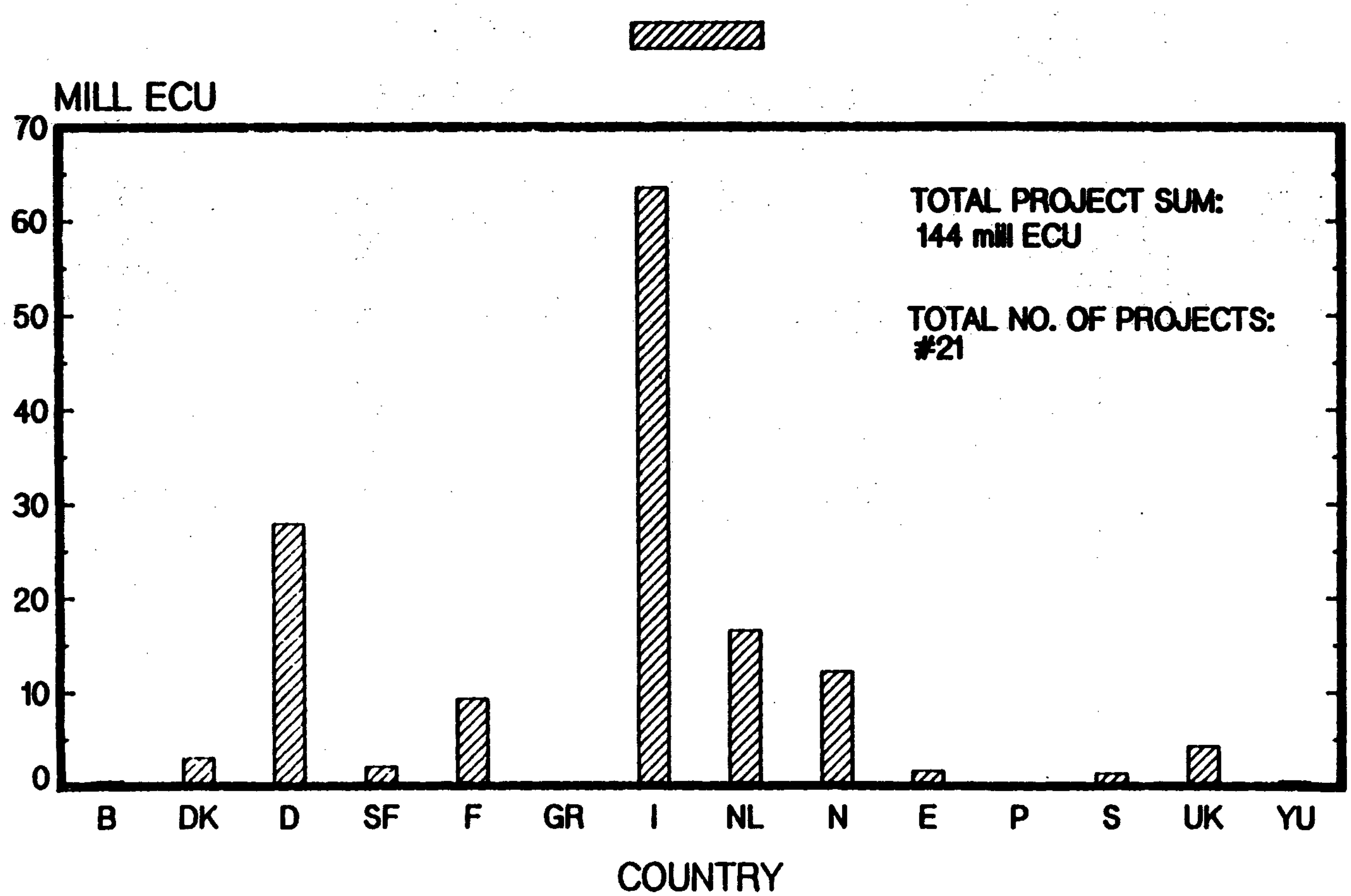
EUROMAR MARKETING STRATEGIES

The first EUROMAR Technology Market held at Scheveningen, in The Netherlands, on 6th-8th September 1988 was an impressive demonstration of this dynamism. The exhibition brought together all the potential participants in sea-related projects (marine scientists, marine managers, companies, developers and inventors of marine instrumentation, etc.). In addition, for the first time, it brought together in a single market suppliers and purchasers of marine products related to the environment. The second EUROMAR Technology Market will be held in Venice from 4th May to 6th June 1990.

EUROMAR's aim for the 1990's is to be a spearhead for the research and business communities in the fight against marine pollution in Europe and worldwide. EUROMAR was established to help science and industry create the necessary tools to observe and record the important environmental parameters in the ocean. Such observations are needed in order to find the best way of fighting pollution, with the aim of achieving "sustainable" development. Thus the market for advanced marine surveillance systems is there, EUROMAR assists the international business community in developing the necessary technological products.

As part of the EUROMAR marketing efforts EUROMAR has also developed an information folder and is now planning a European magazine (working title "OCEAN '99") which will present articles on specific marine subjects as well as marine pollution surveillance technology. The magazine will also represent a unique possibility to advertize technology products developed under the EUROMAR umbrella.

EUROMAR PROJECT COSTS



It should also be mentioned that EUROMAR will be presented at the next EUREKA ministerial meeting in Rome. We think this is important since so many governmental representatives will be present. Their importance for establishing national markets is quite evident since national environmental agencies will be a major user of environmental information.

EUROMAR PROCEDURES

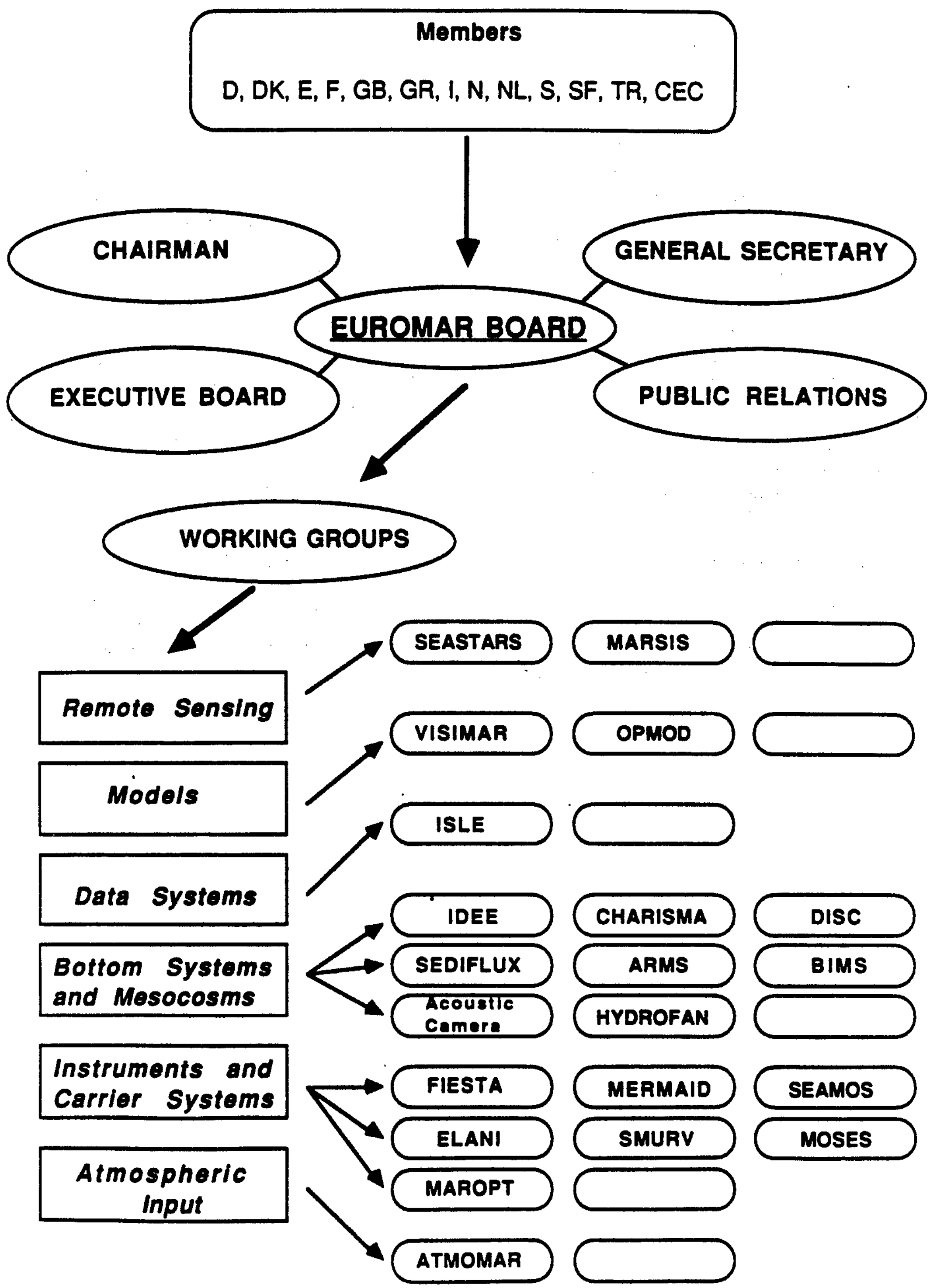
As mentioned EUREKA observe the project EU 37 EUROMAR belongs to the so-called umbrella projects, i.e. a mother generating daughters within the working areas described by the EUROMAR terms of reference. This is reflected in the EUROMAR structure (Figure 2). The twelve member countries and the Commission of the European Community send one member, alternate and advisor resp. associated foreign institutions one observer into the central steering body, the EUROMAR Board. Attached to the Board are the Chairman, elected for a period of two years, the General Secretary, the Executive Board for urgent questions in between the yearly Board meetings and the new formed group for public relations.

The coordination between projects, the discussion of new ideas and the formation of international partnerships by a bottom-up approach occurs during the expert meetings at the international Working Groups. Each daughter project is an offspring from the relevant Working Group and will report here on the progress achieved.

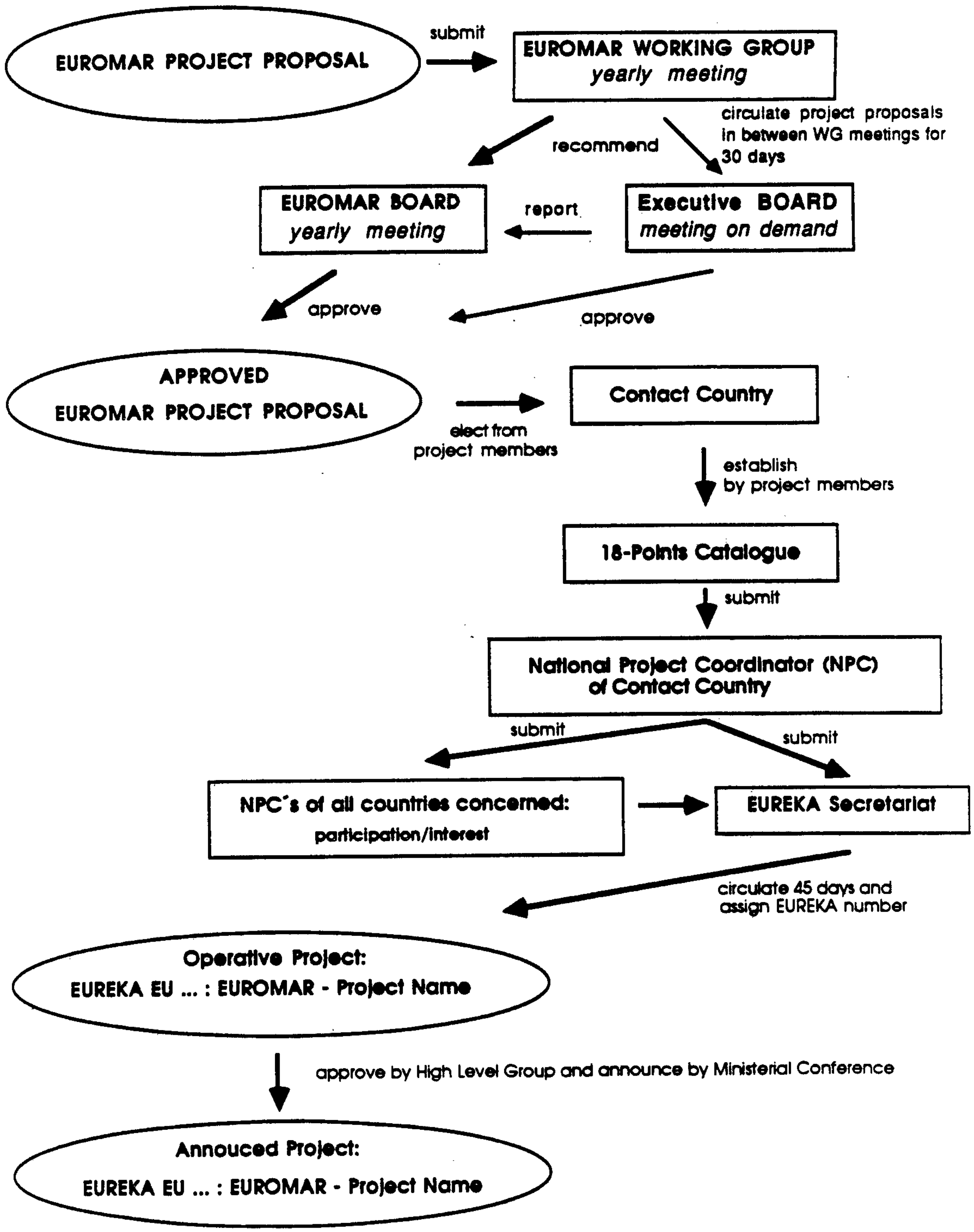
Today more than twenty EUROMAR daughter projects are operative with a considerable span in innovative marine technologies (Table 1). Some 110 companies and 60 institutes/governmental agencies all over the Europe cooperate in these projects and thus demonstrate the joint efforts in a challenging market for the nineties. Due to new EUREKA regulations some projects operative so far under a EU 37-subnumber are just in the process for attaining their separate EUREKA number.

The procedure for the formation of an EUROMAR daughter project is depicted in Figure 3. In contrast to EC programmes EUREKA projects are funded strictly nationally. Thus a close contact to the national EUREKA bodies and the relevant national funding agencies is necessary during the described process.

EUROMAR STRUCTURE



EUROMAR PROJECT PROCEDURE



EUROMAR DAUGHTER PROJECTS

(operative since 6. Ministerial Conference, Copenhagen , June 18,1988)

No.	Acronym	Title	Contacts:
EU ... EU 37/1	EUROMAR - FIESTA	Rules for Standardisation of Field Data Quality D, DK, F, GB, I, N, NL, SF	Dipl.-Ing. Horst Helms Krupp Atlas Elektr. GmbH Postfach 44 85 45 D-2800 Bremen Germany
EU 417	EUROMAR - MERMAID	Marine Environmental Remote-controlled Measuring and Integrated Detection D, N	Dr. H.-D. Knauth GKSS Max-Planck-Straße D-2054 Geesthacht Germany
EU ... EU 37/3	EUROMAR - SEAMOS	Sea Environment Monitoring System I, F, GB, N, SF	Dr. R. Boniforti ENEA-CREA S. Teresa P.O. Box 3 16 I-19100 La Spezia Italy
EU ... EU 37/4	EUROMAR - ISLE	Information System for Local Environments I, D, GB	Ing. B. Boni-Castagnetti Fiatengineering Spa. C.so Ferruccil 12 I-10138 Torino Italy
EU ... EU 37/5	EUROMAR - SEASTARS	System for Airborne Remote Sensing of the Sea D, CEC, I, NL	Dr. Claus Bößwetter MBB-ERNO Raumfahrt RR01 Postfach 80 11 69 D-8000 MÜnchen 80 Germany

(operative since 7. Ministerial Conference, Vienna, June 19,1989)

No.	Acronym	Title	Contacts:
EU ... EU 37/6	EUROMAR - ATMOMAR	Atmospheric Pollutant Deposition to the Marine Environment I, D, F, NL, S	Dr. Mauro Tagliazucca Consigl. Naz delle Ricerche Institute FISBAT Via de Castagnoli 1 I-40126 Bologna Italy
EU .... EU 37/7	EUROMAR - IDEE	Innovative Development of Experimental Ecosystems N, D	Dr. Torgeir Bakke Norw. Inst. for Water Res. NIVA Blindern P.O. Box 333 N-0314 Oslo 3 Norway

Table 1 EUROMAR Daughter Projects

2	EUROMAR - ELANI	Electro-analytical Instrumentation YU, D, DK, S	Prof. Dr. Marko Branica Inst. Rudjer Boskovic Center of Marine Research Y-41000 Zagreb 54 Yugoslavia Prof. Daniel Jagner Chalmers University Dept. of Anal. and Mar. Chemistry S-41296 Göteborg Sweden
	EUROMAR - MARSIS	Marine Remote Sensing Information System I, D, F	Dr. Vittorio Barale ENEA CREA S. Teresa P.O. Box 316 I-19100 La Spezia Italy
7	EUROMAR - VISIMAR	Visualisation and Simulation of Marine Environmental Processes D, F, N, S, SF	Prof. Dr. Jan Backhaus Universität Hamburg Institut für Meereskunde Troplowitzstr. 7 D-2000 Hamburg 54 Germany
3	EUROMAR - OPMOD	Operational Modelling of Regional Seas and Coastal Waters D, I, DK, F, N, S, SF	Dr. Kurt Duwe Hydromod GbR Bahnhofstr. 34 D-2000 Wedel (Holstein) Germany
	EUROMAR - CHARISMA	Characterisation of suspended matter NL, DK, N	Dr. Ing. Arne Loevik Bentech Subsea A/S Wergelandsveien 3 P.O. Box 55 N-7501 Stjördal Norway
	EUROMAR - DISC	Directed Sensor Carrier NL, N	Ing. Frans A. van Dongen Industriele Raad voor de Oceanologie Martinus Nijhofflaan 2 12e Verdieping NL-2624 ES Delft The Netherlands
	EUROMAR - SEDIFLUX	Sediment Flux Profiling I, NL	G.C. Drenthen Stork Servex P.O. Box 80 90 NL-3301 CB Dordrecht The Netherlands
	EUROMAR - ARMS	Acoustic Reflectivity Mapping System N, DK, I, NL	Freddy Pöhner Simrad Subsea A/S Strandpromenaden 50 P.O. Box 111 N-3191 Horten Norway

le 1 Continues

EU 408	EUROMAR - BIMS	Benthic Instrumentation and Monitoring System I, D, N, NL, S, SF	Dr. R. Bonifortl ENEA-CREA S. Teresa P.O. Box 3 16 I-19100 La Spezia Italy
EU 409	EUROMAR - SMURV	SWATH - Multipurpose Research Vessel I, GR	F. de Vuono ITALMARE SpA via delle Rose 50 a Piana di Sovento I-8035 Napoli Italy
EU 410	EUROMAR - MOSES	Mobile Station for Environmental Surveys NL, D, I, SF	Dr. J. H. Stel Netherlands Marine Research Foundation (Sticht. Onderzoek der Zee) Koningin Sophiestraat 124 NL-2595 TM The Hague The Netherlands

(operative from 8. Ministerial Conference, Rome, June 1, 1990)

EU 408	EUROMAR - ACOUSTIC CAMERA	High Resolution Acoustic 3D Imaging System NL, F, GB, N	Ing. C.J.M van Ruiten TNO Inst. of Appl.Physics Stieltjesweg 1 P.O. Box 1 55 NL-2600 AD Delft The Netherlands
EU 413	EUROMAR - MAROPT	Marine Optical Recording System D, GB	Prof. Dr. J. Lenz Institut für Meereskunde Düsternbrooker Weg 20 D-2300 Kiel Germany
EU ...	EUROMAR - HYDROFAN	Shallow Water Mapping Echosounder D, F	Dipl.-Ing. Rolf Ziese Krupp Atlas Elektr. GmbH Postfach 44 85 45 D-2800 Bremen 44 Germany

EUREKA EU191 - AN EUROPEAN ADVANCED UNDERWATER ROBOTICS PROJECT

A R Hedge*, M H Shopland*, M Berta and W Prendin****

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** *Tecnomare SpA, Venice, Italy*

1. Introduction

A major European programme is underway to develop two advanced underwater robot vehicles, involving a collaboration between nine UK and seven Italian organisations. The programme, conducted within the EUREKA framework for collaborative high technology projects, will develop the enabling technologies required to construct advanced robots, and demonstrate these in a semi-autonomous work and inspection robot, and in an autonomous robot for underwater survey.

This paper describes the concepts behind the project, the technical aims and perceived key areas of research, and the structure and organisation. The current status of the project, and the plans for its future, are also described.

2. Project Concept

The project was conceived in 1986 by the two principal partners, Tecnomare of Italy and Ferranti ORE of the United Kingdom. A joint research and development programme was proposed which would lead to the development of two different demonstrator vehicles. These would be more than "technology demonstrators", each would hopefully be a viable commercial vehicle in its own right. Furthermore, the development of the enabling technologies would lead to "spin off" sub-systems which would be marketed separately for incorporation into other vehicles, or for retro-fitting into existing underwater vehicles. The concept is very much a commercial development rather than an academically inspired research programme.

The size of the project was too large for the two principal partners to conduct or finance by themselves, and each principal partner put together a team of other collaborating organisations to join in the programme. All participants work on a partnership basis, sharing the project costs, rather than under a prime contractor - subcontractor relationship.

Under the terms of the EUREKA framework, such projects may be eligible for financial support from the national governments of the participating organisations. The project was put forward for EUREKA status and approval in principle was granted at the EUREKA Ministerial Conference in September 1987.

The research into the various technologies involved is distributed equally between Italy and the UK, but these technologies are targeted at two very different robot vehicles, one to be developed under the leadership of each national group. The Italian group has responsibility for the Work and Inspection Robot or WIR. This is a tethered, semi autonomous vehicle outwardly similar to a conventional ROV. Its tasks are inspection and maintenance of offshore platforms and sub-sea installations. Unlike a conventional ROV, it uses advanced robotic techniques to automate many of the routine tasks normally performed by the pilot, and offers the operator sufficient dexterity to perform tasks otherwise performable only by a diver.

The UK group has responsibility for the Autonomous Robot for Underwater Survey or ARUS. This is a fully autonomous vehicle capable of surveying the seabed at full ocean depth according to a predefined mission. It will be capable of performing tasks usually accomplished by tethered or towed vehicles, but with a much greater "production" rate and much reduced operational cost.

3. Technical Goals

A number of key technology areas requiring development have been identified for each vehicle. The major areas will be briefly described.

For the WIR vehicle these key areas are:

- advanced scene recognition and representation to enhance typically low quality imaging;
- high level control of both the vehicle and any manipulators;
- automatic hovering capability, allowing the vehicle to maintain a fixed position relative to the structure without operator control;
- real time positioning systems capable of operating close to and within complex underwater structures;
- automated track following (eg of weld seams) by the end effector.

Provisional specifications for WIR are:

- Operating depth	300/1500/3000 m according to configuration
- Dimensions	2 x 1.2 x 1.2 m
- Weight	1.5 - 2 tonnes
- Power supply	via umbilical
- Max sea current	1.5 ms^{-1}

For the ARUS vehicle, the key technology areas are considered to be:

- artificial Intelligence techniques for world modelling and mission planning;
- long range, high accuracy underwater navigation;
- high efficiency, long endurance energy storage and power generation systems;
- advanced acoustic imaging sensors;
- advanced construction materials and techniques.

Provisional specifications for ARUS are:

- Endurance	2000 km or 240 hours
- Depth	6000 m
- Length	10 m
- Power supply	self contained, depth independent

4. Organisation

The project has been separated into four distinct phases for planning and funding purposes:

- Phase I
  Project definition, conceptual design studies

- Phase II
  Research and development of enabling technologies
  Design and prototyping of sub-systems

- Phase III
  Demonstrator vehicle development and build
  Integration and testing

- Phase IV
  Design and production of commercial vehicle prototype

In the UK, the organisations involved, and their roles in the project, are:

- Ferranti ORE Ltd (Project Management, Project Definition, Acoustic Imaging, Acoustic Communications, Acoustic Positioning, Data Storage Architectures)
- British Maritime Technology Ltd (Vehicle Hydrodynamics, Vehicle Hull/Materials, Propulsion Systems)
- Cambridge Consultants Ltd (Long Range Navigation)
- Heriot-Watt University (Knowledge Based Systems, Computer Architectures)
- Institute of Oceanographic Sciences (Mission Analysis, Mission and Support Requirements)
- Marconi Underwater Systems Ltd (Energy Systems, Availability, Reliability and Maintainability)
- Transfer Technology Ltd (Man/Machine Interface, Acoustic Imaging Transducers, Radio Communications)
- UKAEA, Harwell Laboratory (Non Destructive Testing Techniques)
- University of Strathclyde (Payload and Sensor Handling)

In Italy, the following organisations are participating:

- Tecnomare
- AGIP
- Ansaldo
- ENEA
- Elsag
- Riva Calzoni
- Saipem

In both countries, financial assistance is provided by government agencies, although the major part of the overall project cost is provided by the participating organisations. In the UK, Phase I of the project has been supported as part of the Department of Trade and Industry's Advanced Robotics Initiative.

5. Current Status and Future Plans

Phase I, the project definition study, is now substantially complete. At the time of writing this paper, the final report and executive summary are being compiled, the bulk of technical work having been completed by the end of January 1990.

Detailed planning is under way for the development phases, and each government is considering applications for support of the development phases. It is hoped that funding and contractual arrangements will be in place during early to mid-1990, to enable a prompt continuation to the development work.

6. Conclusions

A major European project, involving sixteen partners and two government departments from two different nations, shows that there is a significant level of interest and determination within Europe to succeed in advanced underwater robotic. The collaborative, cost sharing organisation, together with a level of government support, enables companies, research institutes and academia to be involved with a project the scale of which none could afford alone. On the other hand, with such a collaborative project, there are many more obstacles to success than the purely technical. This project is as much an investigation into the realities of multinational, multi-partner, part-funded research and development as it is an advanced robotic project. The technical and project management difficulties faced by such a project are immense. The commercial, contractual and funding problems overshadow these already immense difficulties, and it is these that will eventually determine the project's success.

THE GLOBAL IMPLICATIONS OF CONTINUOUS GAS SEEPAGES

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INTRODUCTION

Natural seepages in the marine environment include groundwater, volcanic and hydrothermal fluids, and petroleum fluids. Of these the last three contribute substantial volumes of gas to the hydrosphere and ultimately the atmosphere, including both carbon dioxide and methane, the two most important 'greenhouse' gases. This paper will concentrate specifically on the petroleum seepages of the continental shelves, and will refer to one example, a seepage site in the North Sea. It will describe the features which are associated with such seepages and comment on their significance to the global environment.

NATURE AND DISTRIBUTION OF PETROLEUM SEEPAGES

In certain parts of the world natural seabed seepages have been known for considerable periods of time. For example the first Europeans to visit the Gulf of Mexico and the coast of California reported vast oil slicks and discovered that the indigenous Indians used pitch to water-proof their canoes and drinking vessels. Wilson *et al* (1974) estimated that natural seepages introduce between 0.2 and 6.0 (best estimate 0.6) million tonnes of petroleum per year into the marine environment. Products of the seepages vary from tar to crude oils and gases. The term 'seepage' covers both the bubbling of gas ('macroseepages') that can easily be detected and observed, and the small-scale emanation of microscopic bubbles or hydrocarbon compounds in solution ('microseepage'). The former may be identified by a plume rising from the seabed on echo sounder, sides can sonar or seismic records, whilst the latter may only be located by the analysis of the hydrocarbon content of the near-bottom sea water.

Generally the nature of the seeping fluid is determined not only by the nature of the fluid produced by local source rocks, but also by the depth of the petroleum-bearing rocks and the nature of the overlying sediments. In the Santa Barbara Channel, California, an area which has been described as having the highest concentration of natural seabed seepages in the world, oil reservoirs occur at very shallow depths and are covered by a thin layer of unconsolidated sediments. Fractures in the anticlinal structures which form the reservoirs of the numerous oil fields provide convenient pathways along which the petroleum, tar, crude oil and gas, can migrate to the seabed. Where the origin of the petroleum is deeper the ability to migrate to the surface becomes restricted to those hydrocarbon compounds with a smaller molecular size and which are more soluble in pore water. For this reason in areas such as the North Sea the petroleum gases, and in particular methane, are the most important seepage fluids.

SEEPAGES IN THE NORTH SEA

In the North Sea the thickness of the Quaternary sediments (up to 1,000 metres in the northern North Sea) inhibits migration, yet reports of macroseepages at three locations have been published: U.K. block 15/25 and Tommeliten in Norwegian block 1/9, (Hovland and Sommerville, 1985; Figure 1) and further north in the Norwegian sector (Sweeney, 1988). This apparent scarcity does not necessarily indicate a paucity of seepages, rather it may be a reflection of the failure to identify them, the incomplete survey coverage and the confidential nature of much of the relevant data which has been acquired by the oil industry.

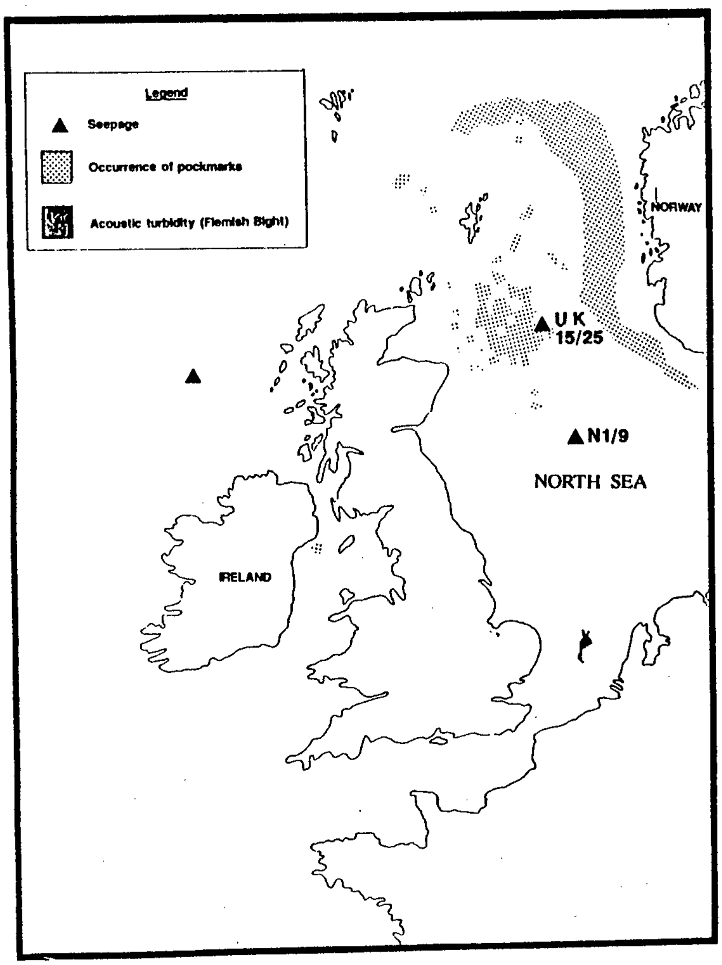

Fig.1 Distribution of gas seepages, large areas of shallow gas and pockmarks around the British Isles. (After Hovland and Judd, 1988)

In order to gain a more complete appreciation of the distribution of seepages in the North Sea it would be necessary to collate evidence from geochemical surveys and to determine the distribution of shallow gas and seabed features associated with seepages.

Geochemical surveys

Geochemical surveys, in which the hydrocarbon content of bottom waters and/or seabed sediments is determined, have been used in the North Sea on a regional scale to identify areas in which there are oil- or gas-prone source rocks, for example Faber and Stahl (1984) and Gervitz *et al* (1985), and to aid in the identification of specific exploration targets for example Sweeney (1988).

Shallow gas

Gas occurring within 1,000 metres of the seabed may originate from either a shallow biogenic, or a deeper thermogenic source. It may be detected by seismic surveys whilst it is migrating towards the seabed. There are no published maps showing the distribution of shallow gas in the North Sea, however it is known that it occurs in relatively small pockets at various depths over large areas. A sizeable area of acoustic turbidity thought to represent shallow gas has been identified in the Flemish Bight, southern North Sea (Figure 1).

Seabed features

Fluids rising to and through the seabed may cause the formation of features such as mud volcanoes and pockmarks. Of these only pockmarks are widespread in the North Sea. They are formed only where the seabed sediments are suitable (Hovland and Judd, 1988), consequently the area of approximately 100,000km^2 from which they have been reported (shown in Figure 1) does not represent the total area in which there are seepages.

AN ACTIVE POCKMARK: U.K. block 15/25

An abnormally large (700m by 400m across by 17m deep) pockmark was discovered in U.K. block 15/25 during a routine site survey in 1983 (Hovland and Sommerville, 1985). The total volume of the feature was estimated as 700,000m^3. Echo sounder, side scan sonar and shallow seismic surveys all showed a seepage plume rising from the deeper parts of the pockmark and seismic data indicated the presence of shallow gas accumulations at depths of 60-70m, 230-250m and 960-1100m within the 9km^2 survey area, as well as within the seabed sediments immediately beneath the pockmark.

This feature has been visited during four subsequent cruises in 1985, 1988 and 1989 (two). In each case it was found that the seepage activity was continuing. During the 1985 cruise reported by Hovland and Judd (1988) an R.O.V. (Remotely Operated Vehicle) was used to survey the feature visually. The seepage vents were located, gas samples were collected. The gas was analysed for hydrocarbons and found to be pure methane, although piston core samples were found to contain ethane, propane, butane pentane and hexane as well as methane. The seepage rate for the whole pockmark was estimated as 3,000 litres per hour (at atmospheric pressure), a volume considered to be surprisingly small considering the apparent size of the seepage plume.

During the visual survey it was found that slabs of carbonate-cemented seabed sediment were common within the pockmark; this material was similar to that found in other North Sea pockmarks, and at seepage sites elsewhere (see below). As a result of this survey Hovland and Judd (1988) considered the visible epibenthic fauna to be atypical of this part of the North Sea. The fauna was considered to differ from that of the surrounding area in terms of both distribution and character, a greater diversity and abundance being found within the deeper areas of the feature. This conclusion has not been supported by the initial results of the subsequent cruises. Many of the seabed samples collected during 1988 and 1989 were pervaded by hydrogen sulphide and contained a fauna which indicated a 'polluted' site. A more complete description and discussion of the finding of these cruises will be presented by Dando *et al* (in prep.).

As a result of the investigations of this pockmark the following conclusions can be drawn:

1: the seepage activity has continued for at least six years, however the presence of gas accumulations at several depths beneath the pockmark idicates a source of gas at least 1,000m deep which will sustain the seepage activity.

2: carbonate precipitates are present on the seabed within the pockmark; their origin and significance is discussed below.

3: the benthic ecology within the pockmark is atypical of the general area; possible reasons for this are discussed below.

4: the seepage is supplying gas into the seawater at a rate of approximately 3,000 litres per hour.

THE LONGEVITY OF SEEPAGES

Considerable periods of geological time elapse whilst petroliferous rocks remain at depths at which petroleum generation can occur; at least 35 million years have passed since the source rocks of the northern North Sea attained 'maturity'. Migration of the petroleum from the source rock occurs by bulk flow and diffusion, both of which may be slow processes. However the existence of gas accumulations in several separate horizons at a single location suggests the progressive migration of gas towards the seabed. As there is little likelihood of the generation process being interrupted there can be no reason for the migration to cease within the foreseeable future. So, even if individual macroseepage events are found to be short-lived, the migration of petroleum fluids towards the seabed over geologically-significant periods of time supports the contention that seepage processes should be regarded as continuous.

THE IMPACTS OF SEEPAGES

The impacts of seepages are illustrated in Figure 2, and summarised in the following.

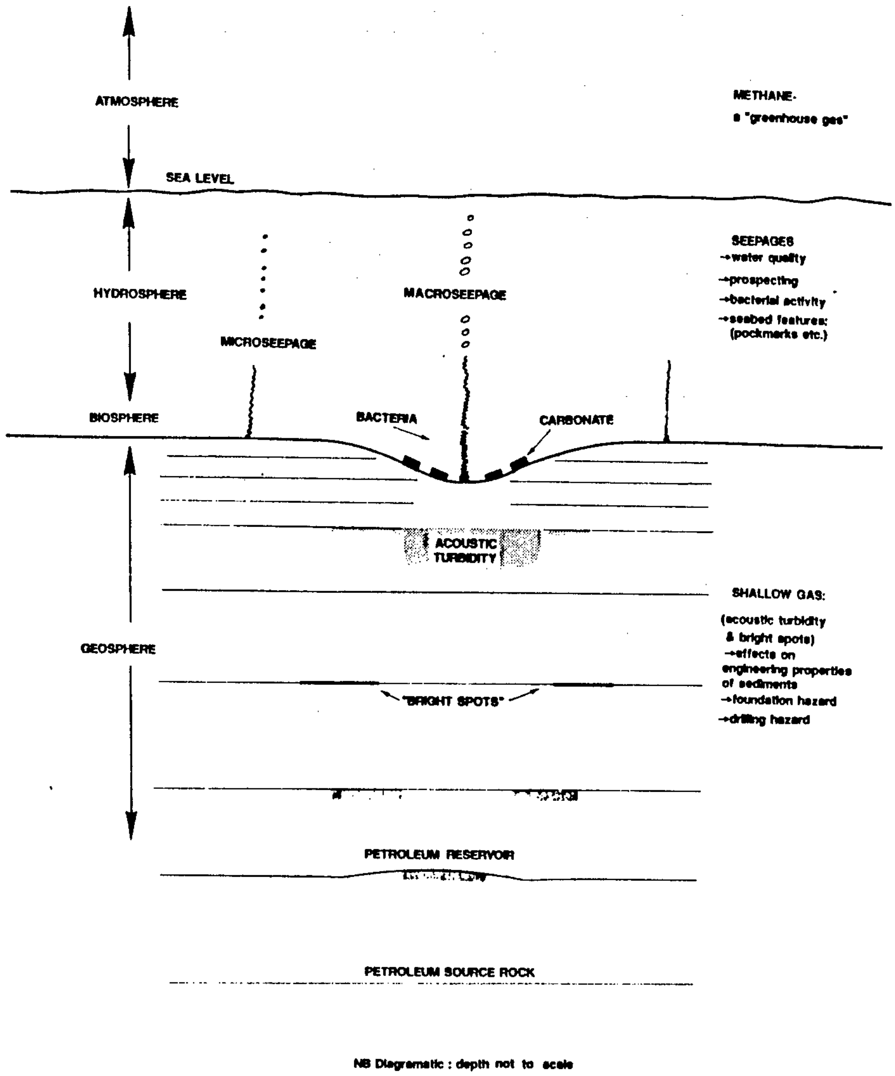

Fig.2 The Impacts of Shallow Gas and Gas Seepages.

Impacts on human activities

Seepages themselves may not greatly interfere with human activities, although without them the geochemical exploration techniques referred to above would obviously not work. Accumulations of migrating gas, sometimes under considerable over-pressure, within the sediments present a potential hazard to drilling and the foundations of offshore structures. 'Shallow gas' accounts for more blow-outs than any other single factor. A recent world-wide survey (Anon, 1985) reported that 22% of 172 blow-outs investigated were caused by shallow gas, and 25% of 600 wells drilled on the Norwegian continental shelf encountered shallow gas, resulting in seven blow-outs and a number of smaller kicks (Aamodt, 1989).

The possible consequences of the presence of shallow gas beneath a structure include; instability caused by excessive platform settlement; a reduction of the load capacity of the piles, skirts or anchors; the erosion of sediments from around the legs or skirts leading to a reduction of load capacity; and the emission of gas with a potential for fire, explosion or a loss of buoyancy. Some of these effects are the consequence of the modification of the engineering properties of the sediments as a result of the presence of gas. All types of structure, piled, gravity, jack-up and floating, could be affected.

In addition the nature and extent of natural inputs of 'pollutants' into the marine environment must be understood before valid assessments of anthropogenic pollution incidents can be made.

Impacts on geology

An association between hydrocarbon seepages and carbonates has been reported from many areas on land, for example Donovan (1974) and Gunatilaka (1989); on the continental shelves, for example Maclean *et al* (1981) and Jørgensen (1976); and the deep oceans, for example Wada and Okada (1982) and Kulm *et al* (1986).

According to Hovland *et al* (1987) and Jørgensen (1976) the carbonates reported from continental shelf occurrences consist of aragonite, high-magnesium calcite and dolomite which are abnormally depleted in ^{13}C compared to normal marine carbonates. It would appear that such carbonates are derived by the oxidation of methane and/or the reduction of hydrogen sulphide, and their presence is thought to be indicative of active methane seepage and bacterial activity. The implications of this method of carbonate formation have not bee fully assessed either for modern sedimentary enviroments or for the equivalents in the geological past.

Implications for marine ecology

Seepages of petroleum fluids may be expected to have a detrimental effect on benthic fauna, however the impact of petroleum as a polluter is apparently dependent upon the particular petroleum compound(s) involved. Generally refined products are more toxic than natural substances.

Bacterial mats have been observed at seepage sites and in pockmarks in the North Sea (Hovland and Judd, 1988) and elsewhere (Grant *et al*, 1986; Davis and Spies, 1980; Bright and Rezac, 1977 for example). In some cases the species present has been identified as the sulphide oxidiser *Beggiatoa sp.*, however the presence of high concentrations of hydrogen sulphide, as reported above from U.K. 15/25, is not inconsistent with the presence of methane. The concentrations of hydrogen sulphide and methane may prove toxic to the benthos. Alternatively bacteria attracted by these gases may represent a source of food for the faunal communities. Studies of the benthic ecosystems of the Coal Oil Point area of the Gulf of California brought Straughan (1982) to the conclusion that the area experiences an input of petroleum which is patchy in time and space, and that consequently the effects are also patchy. Some areas are 'depauperate' whilst others "may actually be trophically enriched". Despite this variation and the distribution of intermediate stages there is a "general enrichment" of the benthic communities over a large area which "may be explained" by the seepages.

With respect to seepage sites in the North Sea Hovland and Thomsen (1989) considered that there is a relationship between gas seepages and the fauna, whilst Judd and Hovland (1989) speculated that higher life forms, for example fish, may be more prolific in areas such as the North Sea, where petroleum seepages provide a source of chemosynthetic energy to an ecosystem traditionally considered to be dependent upon photosynthesis.

DISCUSSION

The estimate of 3,000 litres per hour seeping from the U.K. 15/25 pockmark is equivalent to 17 tonnes of methane per year. This compares quite closely to an estimate, also presented by Hovland and Judd (1988), of seepage rates from a 6,500m^2 area at Tommeliten in Norwegian block 1/9: 24m^3 per day at 75m water depth, that is 43 tonnes of methane per year. These figures, although based on short-term measurements at a limited number of individual seepage vents, make an interesting comparison to previous estimates of the natural petroleum hydrocarbon inputs which are presented in Table 1. The U.K. 15/25 seepage alone represents approximately 2% of the largest previous estimate for the U.K. sector of the North Sea. This seems unreasonable. Furthermore, although reports of only three North Sea macroseepages have been published (see above) it is probable that there are many more; perhaps a few hundred or even a few thousand. If each macroseepage contributed no more than one tonne of methane per year this would suggest that the total natural production of methane in the North Sea should be measured in hundreds or thousands of tonnes.

Hovland and Judd (1988) made a tentative estimate of the total methane production from macro- and microseepages in the northern North Sea based on the U.K. 15/25 figures. Their figure of 2.6 million tonnes per year challenged the validity of Ehhalt and Schmidt's (1978) estimate of between 1.3 and 16.6 million tonnes of methane per year for the world's oceans.

In a review of natural marine oil seepages world-wide, Wilson *et al* (1974), stated that the continental shelf of the British Isles had "low potential" for seepages. This opinion was formulated before the importance of the North Sea petroleum province was appreciated. In view of the current understanding of North Sea geology, the discovery of active macroseepages and the implied presence of microseepages, a reappraisal of this estimate is called for.

The role of natural marine seepages of petroleum hydrocarbons in the global carbon cycle may be more significant than is commonly thought. Models of water quality and marine environmental processes should take into account the introduction of petroleum hydrocarbons from the underlying sediments, particularly in areas, such as the North Sea, which are known to be major petroleum provinces.

TABLE ONE

Estimates of petroleum hydrocarbon input to the marine environment by natural seepage

SOURCE	SEEPAGE PRODUCT	AREA	ESTIMATE tonnes/year	tonnes/1000km²/yea
Wilson et al, 1974	Petroleum	World seas and oceans	(best estimate 0.6x10^6) 0.2 to 0.6 x 10^6	-
"	Petroleum	N.W. European continental shelf	-	0.05 to 2.0
Kornberg, 1981	Petroleum	N.W. European continental shelf	-	0.05 to 1.3
"	Petroleum	U.K. Waters	100 to 300	-
Whittle et al, 1982	Petroleum	Waters around British Isles	< 300	-
Grogan, 1985 *	Petroleum	U.K. Sector, North Sea	300 to 800	0.5 to 1.5
This paper **	Methane	U.K. 15/25 pockmark	17	-
" **	Methane	Tommeliten	43	-
Hovland and Judd, 1988	Methane	Northern North Sea	2.6 x 10^6	-
Ehhalt and Schmidt, 1978	Methane	World seas and oceans	1.3 to 16.6 x 10^6	-

* quoted in Kornberg, 1981

** data from Hovland and Judd, 1988 (see text).

On the assumption that a significant proportion of the seepage gases which enter the marine environment pass through into the atmosphere, it is also important that the contribution of these gases should be taken into account when considering the atmospheric concentrations and the origin of gases such as methane. As methane is the second most important 'greenhouse' gas (see Figure 3) a revised appreciation of the contribution of seepages to atmospheric methane concentrations may influence the current debate on this subject.

This paper has exclusively considered seepages of petroleum hydrocarbons. Major contributions to processes of the geosphere, biosphere, hydrosphere and atmosphere are also made by other seepages, most significantly those related to hydrothermal and volcanic activity where carbon dioxide plays a major role. Again the contribution of seepages to the global carbon cycle may have been underestimated.

ACKNOWLEDGEMENTS

Various colleagues have assisted with the development of the ideas presented in this paper, particularly Martin Hovland. Their unwitting assistance, and that of Bill Scott, who reviewed the manuscript, and Pat Cowell, who prepared the figures, is gratefully acknowledged.

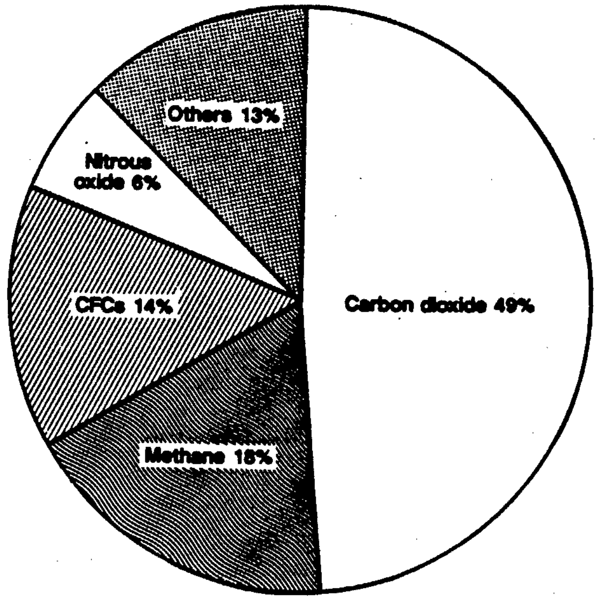

Fig. 3 The contribution of methane and other gases to global warming (after Pearce, 1989)

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Possibilities of the acoustical-hydrophysical method of ocean fronts investigation

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Intensive development and perfection of technical facilities for the ocean study as well as expansion of their functional possibilities contribute to creating of integrated systems for the collection and processing of oceanological data. A good example of such integration one can see on the board of R/V 'Akademik Ioffe' (Institute of Oceanology, Moscow). Complex using of its scientific equipment including satellite reception station MSGS-20, echosounder DEEP SEA, COLOR SONAR, automatic meteorological station WETOS-625, acoustic doppler current profiler ADCP RD VM0075 and CTD unit NBIS MK3B opens new and wide possibilities for the investigations of structure and dynamics of ocean fronts. Quasi real-time analysis of satellite information gives general surface picture of the fenomena interested that optimizes the choice of transects positions for in-situ and echosounding measurements. Due to this optimization it's possible to pay more attention to make detail instrumental and remote investigations of ocean structure thermohydrodynamical parameters without additional time losses for background measurements. We name this strategy as an acoustical-hydrophysical deep-sea investigations method based on the preliminary analysis of satellite surface information. The method involved supported by complex equipment pointed above has been realized already for the study of the North-African upwelling system and a frontal zone of the Gulf Stream cyclonic meander. Data analysis shows a close connection between peculiarities of space distribution of the sound volume backscattering strength and anomalies in the thermodynamicals and current fields of the investigated phenomena. In general case this connection consists in that the quasihomogeneous by their backscattering properties zones lie within certain thermohydrodynamical structures, that also lie within certain theromohydrodynamical structures, that also shows the possibility of their echosounding sensing. Said above is confirmed by examples of investigations of the acoustical and hydrophysical peculiarities of the transversal jets system in the North-African upwelling and the Gulf Stream current up to 800 meters depth.

Mesoscale phenomena in the North Polar Frontal Zone

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There are many data about the mean hydrological characteristics of Norwegian and Greenland sea waters on the base of standard sections with the spacing between the stations about 40-60km. But this information don't allow to investigate the internal structure of North Polar Frontal Zone (NPFZ), where the characteristic scale of the temperature and salinity variability is about 5-50km. It's necessary for the purpose of investigations of phenomena in NPFZ to carry out the special smallscale surveys with the spacing between the stations of about 1-10km.

In the March-May 1985 during the 25th cruise of r/v 'Professor Molchanov' the special complex nature experiment was carried out in Norwegian and Greenland seas. In NPFZ the several mesoscale phenomena were found. For the purpose of identification of this phenomena and for the directioning the vessel to its the IR-images, received from NOAA satellites on a board, were used. For the determination of surface hydrological parameters smallscale variability the contact quasicontinual temperature and salinity measurements were used. The experiment includes four surveys by STD-sounding with the spacing between the stations from 2 to 20km.

During the first survey in the Norwegian Coastal frontal zone near the Lafoten Islands the anticyclonic frontal meander from the surface to the bottom was observed. The characteristic scale of the meander was about 30km. This meandering causes in the upper 30-35m layer the anticyclonic filament of low salinity Norwegian Coastal Current water and lead to the correspondent configuration of surface sharp front. In this connection the TS-correlation of the thermochaline variability in the surface layer was positive, but in deep water - negative.

Similar structure was found in the frontal zone of Norwegian Current during the second survey. From the picnocline to 500m the anticyclonic meander of front was observed. The temperature and salinity in the central area of meander was greater than in periphery of one. Anticyclonic circulation in the upper layer moved the water of the more greater temperature and salinity from the frontal zone, situated 20-30km apart. It resulted in eddy filament formation and upper layer sharp front developing around the meander's centre. In this connection in the upper layer the water of filament of 20-30km width had the greater temperature and salinity than in central 30-km area and than in far periphery of the meander.

During the survey of frontal zone near the Mone's Ridge jointly by the satellite and ship data the several mesoscale meanders, eddies and fronts were found. Under the comparatively cool and fresh arctic water of upper layer the isolate lenslike volume of atlantic transforming water was observed. It supposed was the intrathermocline eddy.

During the survey of the eastern part of the Faroe-Iceland Ridge frontal zone near the Faroe Bank the vortex dipole, consisting of cyclone and anticyclone, was found by the satellite and ship data. The detail survey of this structure was made. The characteristic scale of vortexes was about 30km. Near the base of the dipole the comparatively cool and fresh jet was found. It allow to suppose that the 'mushroom current', similar to described in [1] by only satellite data, was observed.

Author doesn't know any descriptions of such phenomena by ship data.

High-effective multisectional wind propulsor research, seagoing tests and future development

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INTRODUCTION

The use of sails as an ecologically pure and cost-effective means of propulsion for various types of ships is now attracts much interest in many countries of the world. At the present stage of development of this kind of propulsion system a search is continued for the most promising design which must take into consideration a great number of factors associated with technological and operational problems. And one of the main trends of research in this field is raising of the aerodynamic effectiveness of sails.

The multisectional sail is a result of extensive co-operative research and development work, carried out by the Oceanology Institute of the USSR Academy of Sciences, Krylov Shipbuilding Research Institute (KSRI), Hollming Ltd Shipyard (Finland) and Hollming Ltd Materials Technology. This objective was pursued in the development of the sail equipment for the research vessel r/v Akademik Ioffe of the USSR Academy of Sciences, where a wind propulsion system is used as the main means of propulsion for hydroacoustic research purposes.

AERODYNAMIC BASIS

The aerodynamic configuration of multisection wing which is widely used in aviation was taken as a basis for further research work. The requirements for the adaptability to manufacture, safety of operation in combination with aerodynamic characteristics of the wind propulsion unit have resulted in a construction comprising two sails installed on both sides of the vessel, each sail consisting of five identical asymmetrically shaped elements, two of which are turning about the vertical axis when the loads exceed the admissible levels for safety of operation. The elements are fixed between two end plates and taken together they form a slotted arched profile. When in operating condition the sails are turned about the vertical and horizontal axes, while in storm conditions or in harbour they are folded and brought down on to the deck.

A multitude of tests were conducted in the wind tunnel of KRSI. The models differed from each other in quantity of sections as well as configuration of the elements forming the wing profile. Aspect ration and the use of endplates of different configuration were also studied. The sails were even tested on a scale model of the vessel for which they are designed, to determine the interaction between the sail and the ship and to get total aerodynamic forces and moment acting on the ship.

The research performed has resulted in the development of a wind propulson unit consisting of five rigid wings fixed between two end plates and forming an arched slotted profile with camber f=35%. The profile is so designed that as the angle of attack changes the maximum thrust of the sail in the region of critical values will not change over a broad range of angles at the expense of re-distribution of loads on the elements.

In order that an accident due to gusts of wind be avoided the even elements will automatically go feathering, which will decrease several times over the load on the sail and rule out the break-down of same.

When we speak about the main aerodynamic characteristics of a single sail, we must pay attention to the high values of the life coefficient Cl (Cl max =2.9) and the portion of the curve (Cl=fC@C where a is the angle of attack) in which Cl is virtually unaffected by a.

The sailing rig developed was manufactured by Hollming Ltd and installed on the r/v Akademik Ioffe.

'FULL SCALE' SAILS TESTS

The vessel Akademik Ioffe was delivered in the beginning of 1989 and since then 'full scale' trials of the sails have been conducted.

The r/v Akademik Ioffe has the following main dimensions:

Length	110.7m
Breadth	17.6m
Displacement	6546 cub.m
Sail area	186 sq.m

Her sailing rig consists of two elements:

1. Two multisectional sails with the sail area of 80 sq.m each (10m height and 8m breadth);
2. Soft 'sail stabilizer' (jib) having the area of 26 sq.m.

During this tests the data for sails influence on ship propulsion, manourability, rolling in different wind conditions have been determined. The 'full scale' trials has proved a good correlation between the wind tunnel tests, the mathematical calculations and the sails in real conditions. The 'full scale' trials have also given valuable data for the development of both the mathematical methods and the sail itself.

MULTISECTIONAL SAILS POSSIBILITIES

The multisectional sails may be used for different purposes, eg main propulsion, auxiliary propulsion, manouvering, roll damping, etc. Using sails for auxiliary propulsion gives a reduction in fuel consumption of 5-20% on a average. The saving is mainly dependant on the wind conditions and the route of vessel.

Although this type of sails are very effective, the wind tunnel tests together with the 'full scale' trials have given new ideals to develop an even more effective sails. The main ideal of this sail is the conversing multisectional wing of 6 elements. The tug coefficient of this proposed sail is more than twice better than the same parameter of the r/v Akademic Ioffe sails. This sail is yet testing in wind tunnel before design and construction work can begin.

Conversing multisectional sail of special design may be also installed on the high-speed multihull yacht as an alternative for usial sail and wingsails of different types.

Ocean trials of optical axis stabilization system

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In this paper are presented materials devoted to specifications and ocean trials of the optical axis stabilization system (OASS). The optical axis stabilization system included in "Laser scanning wave registration system" (SDV). Two complete sets of the DSV had been installed on board of USSR Academy of Science's ships "Ac. Sergei Vavilov" and "Ac. Ioffe".

The OASS system is intended to be used for stabilization and laser beam scanning on research of sea surface and conducting of wave registration measurement from onboard the ship.

The system consists of the biaxial controll gyrostabilizator, the optical unit, the true vertical axis indication unit and the heave compensator.

Stabilization of optical unit is carried out by means of the gyrostabilizator. There are portable, astatic, controll, treeaxial gimbal Gyro as a sensitive element installed in the gyrostabilizator. The forming of special control signals carriers out the laser beam scanning around the true vertical axis with stabilization of the roll.

The system designed to be connected to the computer, functioning in GPIB standard for the purpose of signal prossesing in real time. The OASS system is absolutely reliable. No service by authorized personnal required.

The horizontally gyrostabilazed platform with built-in heave sensor is one of the units of OASS system. The platform functioning enables to get additional data of the heave and horizontal level motions of a ship. So it is possible to use the unit either for OASS research work or separately from the OASS system.

According to customer's desire it's available to achieve wider range of the system functioning by installation of additional sensetive elements or pertional modification of the basic model design to respond to requirements of the task to be carry out.

In paper disscussed tecnical specifications of the OASS system have been obtained as a result of research work in ocean.

Shipborn laser scanning system 'DSV'

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The Shipborn Laser Scanning System DSV is a unique optical mechanical and electronic equipment which is destined for remote research sea or water surface from the moving ship board.

The 'DSV-1' and 'DSV-2' systems are the prototype versions, which have been constructed as a joint project with Hollming-Electronics Ltd (Rauma, Finland), USSR Academy of Sciences Institute of Oceanology (Moscow, USSR) and the Tula Technical Institute of Ministry of Education (Tula, USSR). These two complete sets of 'DSV' had been installed on board of the USSR ACademy of Sciences' ships named after Academik Sergey Vavilov and Academik Ioffe.

There are some science problems to solve which ship laser scanning system can be used:

- Ecological water surface condition studying,
- Sea surface level and sea waves sensing,
- Sea surface flourescence and Raman dissipation of light in the UV band and visible band research,
- Atmosphere aerozole sensing, and ets.

The DSV system senses the level of the sea surface by sending short laser pulses through the fore mast to the sea. Owing to the light volume dissipation in the sea surface water the back scatterepulses are detected by the optical receiver, which installed near the fore mast top. The time-of-flight is measured for each laser pulse. While sending successive laser pulses, the azimuth angle of the laser beam is scanned in the horizontal level. The time-of-flight signal and the laser beam angle informaiton as well as the ship position information are digitized. The digitized data is further on transmitted to the laboratory computer for postprocessing. Zdditional equipment are needed for the ecological water condition studying, the sea surface fluorescence research and ets.

The laboratory computer data processing software calculates the sea level values according to the measured time-of-flights of the laser pulses and the angle/ship position information. Calculation results produce the wave spectrum data which can be plotted, saved or sent to the other system onboard the ship via subnetwork.

The equipment of the DSV system is mainly installed in the fore laboratory. Some of the units are also installed inside the fore mast. The optical receiver is installed near the fore mast top.

The DSV system includes the following units [USSR patent order No 4648458/10, 13 Feb 1989, G01 c 13/00]: Laser, Optical receiver unit, Optical channel inside the fore mast, Power supply for transmitter/receiver units, Cooling system for laser, Scanning and gyrostabilization unit, Pitch/heave/roll sensors, Control unit, Time-of-flight electronic unit, Laboratory computer interface unit, Laboratory computer, Plotter and Printer.

The DSV system is connected to the laboratory computer via GPE (IEEE-488) interface. The laboratory computer is further on connect to th4e Shipbone Integrated Scientific System via network. An anal recorder may be also connected to the DSV system.

The horizontally gyrostabiliazed platform with the built-in heavy sensor is one of the units of the DSV system. The platform functioning enables to get additional data of the heave and hotizontal level motions of a ship. So it is possible to use the unit either for DSV research work or separately from the DSV system.

- END -

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