INMARTECH '96

International Marine Technicians Workshop

Southampton England
30 September to 02 October 1996

Acknowledgements

I gratefully acknowledge the initial idea from the 1995 meeting of the **International Ship Operators**, to hold a workshop of this type and subsequently, the financial support received from the **European Commission** which made the whole thing possible and allowed me to put into practise all the necessary plans and arrangements.

K.G.Robertson
Workshop Chairman
Scientific Superintendent RVS
September 1997

INNMARTECH '96

INTERNATIONAL MARINE TECHNICIANS WORKSHOP
30 SEPTEMBER - 02 OCTOBER 1996, SOUTHAMPTON ENGLAND

PROGRAMME

Monday 30th September - Mooring Operations

"Strong Currents"
Dr. Harry Bryden - SOC - UK

"Technology of Mooring Instruments in the Ocean"
Mr Scott Worrilow - WHOI - USA

ARGOS and related issues
Richard Winterburn - MES - UK

Tuesday 1st October - Calibrations and Standards

"Analysis Starts With Sampling"
Dr K Kramer - Mermayde - NL

"Operations in support of oceanographic field programmes"
Dr.Roy Lowry - BODC - UK

"Developments in Ocean-Thermometry"
Mr Sven Ober - NIOZ - NL

"Using a primary temperature standard at sea; a case study on WOCE P-15S"
Nordeen Larson - Sea Bird Electronics - USA

"Counting the Cost of Calibration"
Mr Paul Ridout - Ocean Scientific - UK

Mr David Ayres - Isothermal Technology Ltd - UK

Wednesday 2nd October - Fishing Technology

"Micro/meso plankton sampling with the Hydrobios Multinet"
Dr G.J.Brummer - NIOZ - NL

"A new benthos dredge (Triple D) for quantiative sampling of infauna species of low abundance."
Dr M.Bergman - NIOZ - NL

Mr John Dunn - Marine Laboratories, Aberdeen - UK

"The Internet and the World Wide Web"
Dr K Bouton - OCEANIC - Delaware - USA

Dr Harry Bryden (ex Woods Hole Oceanographic Institution, USA) now working at SOC - Research Scientist in Deep Sea Oceanography.

"Strong Currents"

I wanted to talk today about strong currents and at present I am involved in a variety of observations at sea including making hydrographic stations and sections and also mooring work but what I want to talk about today is why we as scientists want to make measurements of current in the ocean. I want to emphasise, by picking the title “Strong Currents”, that we are looking at places where we think currents are particularly strong and where we want to make measurements of them.

In terms of deep-sea oceanography we are presently doing a global programme called WOCE (the World Ocean Circulation Experiment) which involves scientists from all over the world to be actively making measurements in the deep ocean during the period 1990/97. There are many facets to the WOCE programme but the one I am going to talk about today is the moored current meter arrays that were planned as part of WOCE.

In the early 1980's scientists gathered in a series of meetings and put forward the ideas for what should be measured in the global ocean in order to define the large scale ocean circulation. What I would like to emphasise with regard to WOCE moored current-meter measurements is that they are not uniformly spread throughout the ocean and there are very few arrays that are thought to be important in the middle of the ocean. Most are on the western boundary currents to measure the Gulf Stream or the deep western boundary currents in the South Atlantic and also the eastern boundary currents where the currents are relatively strong.

One of the first objectives of WOCE plans was to make measurements in each ocean basin of the strength and variability of the western boundary currents such as the Gulf Stream or the Brazil current. The second objective of the moored current-meter measurements proposed for WOCE was to make measurements of the currents across latitudes of either 25E North in the Atlantic or 30E South in the Southern hemisphere to look at the meridional heat transport across the critical transport line, determining the meridional ocean heat transport in each basin is one of the primary objectives of WOCE. Therefore, at each latitude you can see (*Fig. 1*) in the Atlantic at 25E North there are 3 current arrays and there are 6 current-meter arrays at or about 30E South to show the size of the transport and the temperature that each of the currents at these latitudes are carrying. This was the second goal on the moored current-meter measurements during WOCE.

This is a map of the Pacific Ocean *(Fig. 2)* which is similar in design - a series of arrays at about 30E South and at about 25E North (this is the heat flux measurements) and you can also see in each of the North Pacific and South Pacific some measurements of strong western boundary currents, the east Australian current against Australia and the Kuroshio off Japan. The issues which scientists consider to be important in terms of making deep ocean measurements change over time. Here in the vast Pacific you can see there are only a few spots that the large-scale oceanographers have thought to be worthwhile for deploying moored instrumentations to measure currents and they are in regions where currents are thought to be strong.

Twenty years ago, if we had drawn a picture of where the current-meter arrays were in the Pacific we would have seen many more arrays spread out into the interior and quite a bit of exploration going on looking at the currents and the variability in the interior ocean. During the 1980s there have been a series of arrays throughout the interior of the Pacific but they did not really cover the Pacific but they intended to map out the scale of the variability of ocean currents in the Pacific. After having made those measurements the scientists involved in WOCE decided that the current meters resources were best deployed on boundary currents, in measuring strong currents in the ocean and these days scientists would say that for the interior ocean circulation, they might be better mapped if we used float technology. Floats and drifters were not a subject of this Workshop but perhaps would be a topic for future workshops. There is a great effort during WOCE to map out the interior circulation with floats throughout the Pacific, Atlantic and Indian Oceans. However, we are here today to talk about current-meters and I would like to stress that in present oceanographic science we are emphasising the boundary current measurements.

In the Indian Ocean *(Fig. 3)* there was a disagreement amongst scientists as to whether the heat flux line should be 20E South or 30E South and so you can see there is a series of arrays at 20E South and at 30E South to try and map out the heat transport at those latitudes. Again you can see the emphasis on the western boundary current arrays to make measurements of the strength of the Somalia current in the North Indian Ocean and Agulhas current in the South Indian Ocean.

The implementation plan of WOCE was printed and published in 1988 and it followed a series of meetings during the 1980s and then the plan for the WOCE time period for moored instrumentation were basically laid out. No particular funding or finances were associated but there was a clear statement by the scientists as to what they thought was important in terms of the moorings. It was left up to individual scientists and individual countries to go about and to try and carry out these measurements.

1995/96 was declared to be the year in which the WOCE international programme would concentrate on the Indian Ocean and they would try to get as many of the scientists around the world to work in the Indian Ocean as possible and this was a plan put out in about 1993 *(Fig. 4*) this was the US contribution to the Indian Ocean programme. You can see there is a series of hydro sections in black lines and also the current meter arrays along 20E South which are proposed to be done by the US scientists *(Fig. 5).* There was an international component to the programme, also planned in 1993, with international contributions.

Having recently moved from Woods Hole Institution to the Southampton Oceanography Centre, I was reading these plans for the Indian Ocean and trying to identify how we could contribute here in the UK from moored current-meters to this international effort in the Indian Ocean. What struck me was that in neither the US plan nor the international contributions then envisioned was there any attempt to measure the Gulf current here against the southward flowing Agulhas current flowing along the coast of South Africa. It seemed to me a terrific loss for an international programme that the western boundary current for the South Indian Ocean would not be measured unless something was done about it. That’s like saying you are going to measure the circulation of the North Atlantic without ever bothering to measure the transport of the Gulf Stream so I made an argument here within the UK that we would put out an array across the Agulhas current to measure the strength and variability of the Agulhas current during 1995/96.

As a scientist I see the process perhaps a little differently from you. The process was that we went to meetings for 10 years in the 1980s and we argued about and decided upon what were the priorities for making current meter measurements. Then we made a proposal to our national funding agencies for support for one of these particular arrays and had to support our argument as to why a particular array should be done. Therefore, the next step was, there we were in 1993, writing a proposal to make measurements across the Agulhas current. That involves looking at the historical background and what is known about the Agulhas current and what is not known.

In reading the papers in the scientific journals over the past 25 years it seemed clear that there was a particular spot where the Agulhas current came closest to the coast of South Africa and it was right off Port Edward which is just south of Durban. This looked like an ideal place to measure the strength of the Agulhas current and its variability at a place where we thought the Agulhas current was closest to the coast; so the argument was made and we would deploy a set of moorings across that line.

We put 6 current-meter moorings in a line off Port Edward (*Figs. 6,7,8,9*) across the Agulhas current, approximately 4 current-meters on each mooring, to measure the vertical structure and then on the 2 inshore-most moorings. I thought it was necessary where the current was the strongest to put Acoustic Doppler current meters moored at the top of these 2 moorings so that we could profile upward towards the surface the really strong parts of the western boundary current.

This is where I, as a scientist, end in terms of what I want to do and then I turn it over the experts such as Ian Waddington at the Southampton Oceanography Centre. He had not really done moored Acoustic Doppler Profilers before so we had to purchase them and test them. We also had lots of discussions about what size we might expect the currents to be because they were going to be strong. Ian asked for profiles on what kind of currents I expected to be in this region because when you are in a strong current region with very tall moorings they are subject to a lot of mooring motion and dip and we need to minimise that so that we can accurately measure the currents.

One the most difficult things for me as a scientist, in terms of mooring operations, is the idea that you put out instruments and leave them for a year and you don’t know whether they are working or not until you pick them up, which can be quite nerve racking. During the course of this experiment we got a telephone call one day in

July by somebody saying they have found a buoy on the surface and they got close enough to read our telephone number and so they called us up. They could not pick it up all the way because of the weight of the anchor so they dropped it back in the water telling us where they dropped it. Unfortunately they dropped it in shallower water than it had been moored in so instead of an intermediate mooring it became a surface mooring and it was not really designed for that.

I would like to talk about one other moored array which we are just starting to plan here. It is also a WOCE array for the Strait of Gibraltar but there is an added part to this. The Strait of Gibraltar is a classic place to do oceanography and it has been subject of speculation and scientific hypothesis and even measurements for about 400 years. It is a very narrow channel which connects the Mediterranean Sea to the Atlantic Ocean. It is narrow in the sense that it is only 12 miles across at its narrowest point which we as scientists sometimes call Tarifa Narrows. (*Fig. 11*) The sill section is North of Tangier.

It is a WOCE array on the diagram shown of the proposed WOCE sites (*Fig. 1*) and it obviously a prime place for monitoring the exchange between the Atlantic and the Mediterranean. It is in fact a two layer exchange where the surface Atlantic water comes in through the Strait of Gibraltar and the Mediterranean and the deeper water flows out of the Mediterranean Sea into the Atlantic Ocean. This is what we call a choke point and it is an ideal place to monitor the inflow and the outflow of the Mediterranean Sea.

Recently we have had an opportunity within the European science programmes, who propose to put an array of moorings in the Strait of Gibraltar to try and monitor the inflow and outflow through there for an 18 month period and the key scientific question about the currents in the Strait of Gibraltar is how much variability is there on scales of seasonal to inter-annual, in other words does the size of the exchange between the Atlantic Ocean and the Mediterranean Sea vary on timescales longer than about a week. We have made measurements in the Strait of Gibraltar previously but we have the measurements only lasting for about 6-8 months so we don’t have a good feeling for the seasonal variability in the inflow and outflow of the Strait of Gibraltar.

We are now talking about deploying a monitoring array (*Fig. 10*) **-** an array that would monitor the exchange through the Strait of Gibraltar and it is important not only in the terms of the WOCE programme but also in terms that the EC has two large targeted programmes. One is in the Mediterranean to study the circulation of the Mediterranean Sea and the other is called CANIGO which loosely stands for Canaries/Azores/Gibraltar triangle in the Atlantic so it’s a study of the circulation in the eastern North Atlantic between Gibraltar, the Azores and the Canaries Islands.

The Strait of Gibraltar is actually the boundary between those two programmes, so in one sense we provide the western boundary conditions for the Mediterranean targeted programme for studying the Mediterranean circulation and the eastern boundary conditions for the CANIGO project. In both of these programmes it is important that we put this array of moored current-meters in the Strait of Gibraltar and measure the exchange between the Atlantic Ocean and the Mediterranean Sea. I would emphasise that this is a monitoring array and you can see that two types of measurements are going to be used. One is an array of as many as 6 moorings across the sill section to the exchange between the Mediterranean and the Atlantic. The second, which is primarily of Spanish interest, is to try and measure the exchange in the eastern part of the Strait where it is actually much deeper, but there is an advantage here and I should point out that this is Spanish territory on the tip of North Africa and the seas are basically Spanish so they have an interest in measuring the exchange across that line. Diplomatic arrangements have to be made so that we can monitor moored instruments and leave them for 18 months.

The interesting part about the measurements in the eastern part of the Strait is that there is a new kind of acoustic technique which is a second type of element that might be considered for future Marine Technician’s Workshops. This is going to be basically shooting acoustic tomography across the Strait but trying to measure the flow perpendicular to the current so it is not the way we normally think about acoustics, as when we shoot in one direction with acoustic tomography we normally measure the sound speed currents in that direction. This is actually an attempt to send sound across the Strait of Gibraltar but measure down the speed of the flow perpendicular. Again, this is a programme that we are just starting and this is where my role as a scientist stops until we get the measurements.

I have been working on writing proposals to the EC for support and these moored measurements at the sill. I draw up a little schematic of what kind of instruments I think are necessary and then I turn the job over to Ian

Waddington who has to figure out the best instruments to use, the best way to design the moorings and he has to figure out how to get the moorings on and off the ship, redeploy them - all of these logistical details that fortunately I do not have to carry out.

Dolly Dieter (National Science Foundation - USA)

Q What is the recovery rate on the entire WOCE arrays?

A. I could not give you a real number for this. I think as a scientist that when you put instruments in these very high current regions it is basically a very dangerous business and rather than say what is the recovery rate I would probably say that when we put out the Agulhas current meter array I was really hoping for 5 out of the 6 moorings to come back intact. I would consider it not so good if we did not get 5 moorings back. If one gets trawled by a fishing vessel and we have lost that one, there is almost nothing we can do about that and then we had some trouble with another mooring so that time we basically got 4 ½ out of the 6 moorings back and I would say that was a success. If we had only got 3 moorings I would have felt that it was unsuccessful. Different regions of the ocean have different difficulties in terms of putting moorings in. I think that eastern boundary regions in the ocean are typically ones where there is really very heavy fishing and it is in these regions where I think it is unpredictable what you are going to get back.

Geert Jan Brummer (NIOZ)

Q Aren't we as scientists naive in planning mooring operations at relatively shallow depths close to the continental margins where fishing is quite a threat to the mooring operations? Is there a kind of strategy that we could use in order to minimise the loss of instrumentation or in some other way make the planning less naive in the sense that you plant 8 moorings and you want to get 8 out?

A. There are indeed developing techniques for mooring Acoustic Doppler current profilers that have been coming along quite strongly in the last 5 years and indeed that is the way our thoughts are going for the Strait of Gibraltar and we would like to moor the Acoustic Doppler profiler at the ocean bottom and then profile up through the water column. The ADCPs are capable these days of profiling between 300 to 400 metres in the vertical. Beneath the Agulhas current we did not come all the way up to the surface we moored the shallowest instrument 400 metres below the surface so as acoustic technology extends that depth range - yes we will be able to have safer moorings.

One of the problems, however, is that we do not have remote sensing techniques (which I would call acoustic ADCP techniques) that will measure the temperature and salinity structure of the water column, so one of the problems in the Strait of Gibraltar is that we want to be able to locate the interface between the Atlantic and the Mediterranean water all of the time and so we will not only put an ADCP on the bottom to profile the currents up to the surface but we will put a more high risk mooring that extends up through the water column because we need the temperature and salinity measurements to monitor the interface. Hopefully we will only have to do that for a short time because we think something in the acoustics will tell us where that interface is but we must do calibration at least initially to assure ourselves that we can measure the interface with the acoustics.

Ken Robertson (RVS)

Q. You are concerned that mooring instruments in the sea for a long period makes you feel uncomfortable because you don't know if it is working until you recover it. There are techniques I suspect for transmission of data from the sea-bed and from submerged instruments to the surface to reassure you at frequent intervals. Was this considered?

A. On the critical instruments we put ARGOS beacons and I see we are going to talk about ARGOS technology. We have had a mixed result with the ARGOS technology and I would say that the first time we tested the ADCP we put a mooring out and the instrument came up to the surface and the ARGOS beacon came on and we got the fixes from ARGOS but they came to somebody's in-tray who was on holiday for 3 weeks and so the fault is not always in the technology that is available, it is in the human interface sometimes.

Our most recent experience in the Agulhas was an ARGOS beacon that did not come on and consequently, one of the instruments was floating at the sea-surface when we were out recovering the other instruments but we had not had the warnings from ARGOS and so in that case we wonder who is playing with us. When the mooring group arrived home, the next morning the ARGOS beacon started bleeping "here I am - come and get me". Then they had to get on a plane and go back to South Africa to locate the mooring. In this case there was something in the switch on the buoy did not operate quite right. So you can see we have had our difficulties, even with the ARGOS technology.

Q. There are people here from many countries and I understood from your talk that even though this is an international programme, each nation has to look to its own needs and its own sources of funding. Is there more room for international cooperation between the technologists and technicians.

A. One of the benefits of the WOCE programme is that when we made measurements 10 years ago we made them with Spanish and Moroccan scientists on Spanish ships in some cases. When we made measurements in South Africa we used a South African ship in two instances and we had South African scientists and mooring technicians to help us and I think the exchange of the local information and knowledge of the sea conditions there and also the sharing of the expertise in the actual mooring operations has been extremely good. I would like to see that a lot more.

As a side-issue to the mooring work in some of the large scale WOCE hydrographic sections I have been involved in, going across entire ocean basins, the mix of international scientists on board making these measurements is extraordinary. The last time I want across the Indian Ocean we had scientists from 12 different countries working and almost half came from the US but the other half of the scientific party came from many different countries and it is one of the most valuable social and scientific aspects of WOCE.

Kees J M Kramer (Mermayde, The Netherlands)

Q. Can you get your equipment insured?

A. I would have to get someone else to answer that.

Q. How do you sell to the European Commission a programme that you have lost a substantial amount of instruments?

A. We haven't had to do that yet. However, proposing to MAST (Marine Science & Technology) programmes within the EC, it does worry me about proposing to make measurements in the Strait of Gibraltar and that there is not a recognition that there could be significant loss of instruments. As scientists we have usually been prepared to take that risk but I think we have been up front with the programme managers and explain that there is this possibility of risk and so forth. The problem is substantial enough that it needs that kind of work. I have always assumed that if we did lose a lot of instruments, replacement instrumentation might have been forthcoming but I don't have that same feeling with the MAST programme managers.

I was recently at the initial conference for the CANIGO project for which we are supported to do measurements in the Strait of Gibraltar but the programme manager made some blanket statement that if we didn't get 95% of our instruments back we were incompetent. That is easy for him to say but if he has an attitude like that they we are going to have to do safer projects in the future not the critical ones. Therefore, there is an educational aspect that needs to be made with Brussels these days about how dangerous it is putting moored instruments in critical regions. I would not only include the Strait of Gibraltar but high activity fishing regions where obviously we really need the information about the currents and the variability but they are even more dangerous than the Strait of Gibraltar in terms of losing instruments.

Denis Heiden (Cousin Freres)

Q. I would like to revert to the previous question regarding being naive wanting to moor current-meters in shallow waters. Speaking particularly about the Agulhas current meter array, I spent quite a number of years coasting between Angola and Mozambique up and down this coast and all I can say is that the area off Port Edward is virtually deserted and any fishermen would normally be working out to about the 100 fathom mark because it drops down so steeply from there and there is nothing to do for them. I feel this is a low risk area, there not being many fishermen in that part of the world.

Mr Scott Worrilow - Manager of Sub-Surface Mooring Operations for Woods Hole Oceanographic Institution (WHOI)

"Technology of Mooring Instruments in the Ocean"

I am going to explain to you some of the procedures and experiences I have had regarding moorings, instrumentation and some of the special situations and procedures that I have come up against over the years. To begin with I would like to point out that Dolly Dieter was kind enough to bring various copies of a publication that has recently come out from Woods Hole regarding the Buoy Group. There have been a few select individuals in this group, one of whom is David Simoneau who has been a very key player in deep water oceanography for over 30 years. David has been a mentor to me, has been for many years and has taught me a great deal about some of the "ins and outs" of going to sea and doing the work.

Jerry Dean who was another Engineer at Woods Hole, wrote a paper which was presented back in 1982 entitled "Ocean Current Measurement Reliability: An Engineers View" (*Institute of Electrical and Electronic Engineers, USA - Special Working Conference on Current Measurement 19-21 January 1982*). Jerry wrote in that paper that the key to a scientist's success is a technician - having a good technician who is self-motivated and well educated is really the key to a scientist's success.

A seagoing technician is more than the going to sea part - it is the logistics, the ordering, the instrument preparation, ship concerns, as well as hardware, surface and sub-surface moorings, new innovative things regarding instruments, wire rope versus alternatives.

I started with an interest in this field back in the early 1970s when I attended Florida Institute of Technology with a joint major of Marine Biology and Physical Oceanography. I went on to get my degree in Electronics and I started working with Woods Hole in 1978 as an Electronics Technician. Over the years I have come up through the ranks and am now manager of the Sub-Surface Mooring Operations. In the 18 years that I have been with Woods Hole I have made no less than 75 cruises and spent over 4 years of these eighteen years at sea. It probably does not seem a lot to you but it seems a lot to my wife sometimes! My first claim to fame was in 1986 when I sailed as Chief Scientist for the R/V Knorr. Again in 1989 I was asked to be Chief Scientist on the RRS Charles Darwin for an 18-day cruise and during that cruise 6 of those days were steaming time to and from the site. We conducted 24 mooring operations in 12 days - that's two full sub-surface intermediate moorings per day for 12 days straight. Having done that I personally slept for about 36 hours.

The Buoy Group was originally started in 1959 to be a central mechanism for mooring operations for Woods Hole. Over the years they have had a lot of initiative to create a lot of new procedures and ideas for mooring operations. In 1959 we were lucky to have success with one month moorings; the mooring technology at that time was very haphazard to say the least - a lot of the mooring components were nylon and synthetic ropes and they really do not stand up. A lot of the work was coastal work the deep-water work was also a problem in the beginning. Failure of terminations, splices of the nylon, something as simple as a cotterpin and a shackle could destroy a mooring in a very short time.

When I started in 1978 the average mooring life was one year and we were having quite good success. In the early 1960s the success rate was about 50% recovery of equipment and of that recovered equipment about a 50% data return. By 1978 the recovery rates were up over 90%, with 90% data return. We are now on sub-surface moorings deploying routinely for 2 years at a time with the capability of going to 4 years or longer. One of the problems with the longer 4 year deployments is what do I do for 3 years - we cannot put the equipment in the water for 4 years and expect to keep funding for the operation, so unless we can get multiple projects where you can put something new in the water each year, you can't keep working. Our deployment now for sub-surface moorings is for 2 years.

We are now having a very good success rate with our deep-water surface moorings where we can keep these things on station safely and quite easily for 8 to 9 months. A surface mooring is a different animal, with different technology completely from sub-surface and I am going to try to cover both sides of the coin shortly.

Standing Operating Procedures

The one sure thing about Standard Operating Procedures is that there really are none for deep-water oceanography. Something is going to go wrong - you have to know where things stand and you have to be aware of all the "ins and outs" of what needs to be accomplished as early as possible. You need a mental picture of the entire operation from the inception of the scientist when he decides he wants to put a project in the water then this is when you need to get you ideas in a row and really start thinking about everything from the major portions of the mooring, the instrumentation and components of the mooring itself - right down to the 25 cent batteries that you need to back up a memory system inside an instrument and the 2 cent cotterpins required for each shackle. It is knowing everything about that mooring and that is out of the scientist's hand to some extent and taking the responsibility of working on the moorings to get things accomplished.

The better a group of people work together, the better you understand each other then the better the chances are of getting everything accomplished successfully - for the scientist, for yourself and for others who help you out and to assist in the operation. No operation is a one-man show. If you think it is then you need to rethink your ideas. You have to rely on other people and at the same time you have to be willing to allow guidance and show guidance to other people who may just be starting, so that these people know that they can draw from you on their projects and then sometime you may need to all on them to help. If you are going to see and there are ancillary projects on the cruise, if you have the responsibility of Chief Scientist or even if you are going as a Technician, I strongly urge people to understand as much about the ancillary projects as possible during the cruise so that should they run into a problem you are able to possibly help them out to get the cruise back on schedule. So many times at sea I have found that when people are done with their portion of the project will just go off to their cabin and read a book or on the UK boats where they still have a bar on board, they go to the bar and have a couple of beers. If you can get involved with the overall picture and can help everybody to whatever extent you can it is to everyone's advantage, so you can't go into a cruise close-minded. You have to go in open-minded in as far as being able to take suggestions from people, being able to weigh those suggestions to see if you can make the decision and also help others.

There are a few things about standard operation procedures which are standard throughout:

1. Murphy's Law - In oceanography Murphy is alive and well and if something is going to happen it will, so make plans for compensation for any possible thing that may go wrong.

2. Although I will help people out quite routinely, poor planning on your part does not constitute an emergency on my part. There has to be times when you say no - I don't say no very often, but there are times when scheduling and so forth just won't allow it.

3. There are the six P's of oceanography - and that is Prior Planning Prevents Piss Poor Performance.

Needs of the Scientist

When a Scientist comes to me and starts planning an array I need to get in on the bottom line to prepare my portion of the budgets for them. This allows me to know what I am getting into and I try not to forget anything. I really feel that as the seagoing technician it is my job to perform what the Scientist needs to get done. The scientist needs to concentrate on their science, possibly on his next project maybe 2 or 3 years down the road. You heard Harry talking earlier saying his portion of the Agulhas thing was actually brought to mind in the late 1980s and did not get implemented until 1995. In order for the scientist to keep getting funding they have to keep thinking about what is their next goal so they need to have my assistance. All the scientists I work with are very at ease - they come to me and say "we want 10 moorings, 35 current meters - this is kind of where I want them to go and this is kind of what I want the mooring to look like." I give them the budgets and my ideas and things that they need to keep in mind.

All the scientists I know are very intelligent people and they really don't want to know all the 'ins and outs' of putting a mooring or an array in the water. By the scientist allowing me to take over responsibility for the array, then I can remember the extra shackles for the thingamajig which the scientist calls his "new toy". The scientists buy new toys and as long as I can get into it, I can make sure I can have the 15 extra shackles on board when we sail and we can put his thingamajig in the water. I let the scientists do their science and they let me do the planning and logistics and the leg work, in order to put the array in the water safely and expeditiously.

There is not a science project that goes in the water that can't be considered a success unless it is done safely. Some of the specific operations will vary with every cruise depending on the equipment, the vessel you are using, the equipment that is actually available and specifics really have to be addressed at the time.

Adjustments will have to be made many times during the time that the procedures are taking place.

Quite a few years ago I was working on a Spanish Research Vessel and I don't speak much Spanish and the crew members on that vessel didn't speak any English whatsoever. I stepped on board and started talking with the Bosun and I knew immediately that he didn't understand me, so I had to run the deck and do the deck operations on that vessel and I was really quite surprised that I was able to get enough information across to the crew members to tell them to pay attention to what I was doing on deck. After the deployments were done, I was really quite surprised thinking back about how quiet the deck actually was during the operation because the crew was so intent on watching my hand operations for operating the crane, the A-frame, whatever, that there was no talking going back and forth. About 5 minutes later the Bosun came back out on deck and, I think we all know that the Spanish do tend to be a little bit boisterous and vocal, and the noise level was incredible, with the Bosun shouting back and forth to all the crew members with his hands in his pockets!

Things can get done and you can work together with people on a different ships and I have seen many times that you do the same operation over and over and over again. Whether it is putting a CTD in the water or a mooring in the water, if you have done something a number of times you do get into a routine but you can't have such a closed mind that you can't be willing to change that routine because of the available equipment that day. You have to be ready to 'punt' - to change your operation procedures according to what presents itself at the time whether it be sea conditions, or whatever.

Stubbornness, pigheadedness - I don't like it and I don't like other people on board to have it. I have sailed with people that are stubborn and pigheaded and I don't work well with them. The only thing I can say here is leave the stubbornness and pigheadedness home - leave it on the beach because you will get along with your fellow scientists members on the cruise as well as the crew if you are able to work with them people. I learned a long time ago watching other people that it is a lot easier to walk across gangway on a ship whether it is a ship from NERC or whether you have never been on a vessel before, it is a lot easier to cross that gangway with an open mind and be ready to work with people than going across that gangway and making demands and placing orders on the crew.

Safety

Personal safety factor is utmost in this operation. An operation cannot be considered successful unless it is done safely, without any personal injury or equipment damage. Equipment is going to get damaged but equipment can be fixed. Personal safety takes number one place in what happens on board. To do this you need to take extra care. I haven't been on a trip yet where there has been a serious injury and I'm glad about that. You must keep things slow and controlled during mooring operations. Again you might get into a bind sometimes because of the weather and it is hard to keep things slow all the time but if you have to speed something up in order to catch up that's fine but things don't have to happen at such a haphazard pace that you've got 7 people running around who do not know where things are going. Keep people aware of the operations, keep people informed of what is happening. This is very important and I find that when I'm working on deck people have specific responsibilities. David Simoneau who goes to sea with me, normally runs the deck . If I'm going to sea by myself I'll run the deck. David and I work very closely together and it is good to have people that you can work together with. When David and I work together he runs the deck and I keep looking to see what is happening, looking for bad leads or bights which might break and cause somebody damage or harm - heavy loads overhead and keeping an eye open for anything that could possibly go wrong. Murphy is alive and he works on board too!

If I have new people going out on a cruise for the first time I think it is important to take these people as a kind of observers for the first trip or two than actually just throwing them straight into the operation. Many times we have the new man just sit up on the deck above and watch a few operations before we actually let him come down on the working deck. This is both for his safety and for your safety. They just have to watch and learn the routine slowly.

Logistics

This is one of the most difficult portions of the job. It means trying to get everything together in one place ready to go to sea when the ship is scheduled to sail. I have had to deal with shipping multiple containers to different countries, as well as small shipments across State lines. When it comes to shipping 'Murphy' happens. I think there is a freight company with the slogan ... "When it absolutely positively has to be there ...." - my conclusion to that line is use somebody else. The quicker you need something the greater the chances are that you are not going to get it on time. If you are relying on next day or second day delivery routinely, I think it is time you reconsider you plans and your scheduling and start getting things out the door quicker. If I expect container shipping times to take 2 weeks, I usually allow 3 to 4 weeks. Air shipments - if is to take 2 days, I'll give it a week.

Work in foreign ports can be more difficult than working in your home port. I normally allow two to three times longer working in a foreign port to get the same job done than it would do in Woods Hole.

When you go to port with extra time, two or three times longer than you might expect, if you get the job done in time, go to the beach. Its better than rushing at the last minute putting the equipment together after the ship has sailed. After the ship has sailed is not the time to worry about "what have I forgotten". Don't get to a ship the day before it is going to sail because something is going to go wrong. You can be in contact with the Agent and the Agent says "Oh sure everything is there, the containers are sitting on the quay ready to go on the boat" - you arrive only to find out that in fact the Agent didn't quite understand you on the telephone and you find out that the ship has sailed with your container on because of a stevedore strike and the container is not due back in port until next week. You get word that the container is going to get there, you arrive and are informed there was a ferry breakdown over the weekend, there is a 250 car back log of tourists and the tourists take precedence over commercial traffic. The logistics of shipping really take a lot of time and the logistics take more time than they should but you have to get through it.

Budgets and Reduced Funding

Over the years there have been more constraints put on budgets for projects, reduced money and consequently we have been forced to find other ways to conduct the operation using less money and less people. Not too many years ago things were pretty 'fat' with regarding to funding and projects we were going to sea for a typical Buoy cruise with 6 or more people. At that same time the ships were very well manned, almost to the point of maximum. Therefore, things were getting done quite easily. Over the years as competition got stronger for the funding, in order to cut the costs of doing business we started going to sea with fewer and fewer people. Shortly after that the ships started coming under budgetary constraints as well, cutting back the number of hours they would allow crew members to work. So things got a little bit tight - all of a sudden its a Catch 22 situation.

The scientists had become accustomed to going to sea with few people in the science party causing lower budgets and they weren't really willing to bring the budgets up again to support people. At the same time the scientists had gotten used to allowing the ships to supply a portion of man-power. Now the ships don't have the manpower, so it has become necessary to me on my operation not to go a with too many people and allow the cruise to be jeopardised through lack of man power but I am definitely going to sea with fewer people now than I used to. I know that my instrument inventory is about 90% of what it was in 1978. Then we had 6 people doing a job that I have 2 people doing now.

Equipment Considerations-What is going to be needed for the moorings?

The primary and key thing is the Recording Packages and Current Meters. When a scientist comes to me with a project at the planning stages I will reserve his equipment at that time to make sure the equipment is on hand if and when that project ever gets funded. I do make it a policy that I will loan equipment to other people on a "not to interfere basis". If somebody needs some pieces of equipment for two months and I don't have anything scheduled for 6 months, then I will lend it to them for a relatively small labour cost to get the equipment ready. If I am loaning equipment to someone who is not a primary player, I loan it out on a replace if lost or broken situation.

With my own projects I have enough inventory that if I lose an instrument or two I'm not going to worry about it. I don't like to lose equipment, the scientists don't like to lose equipment but I think I could still go for quite a few years before I get down to some level where I would really be in the hurt locker so to speak should I not be able to replace the equipment. I normally do not try to buy new equipment with each project but I will, if need be, buy a couple of pieces of small equipment but for the most part I am living on an inventory that was built up in the 1960/70s when most of it was bought, either with National Science Foundation money or Naval Research money for the Buoy group back in the days of the big buoy cruises that we got used to.

You also need to keep in mind if there are any extra little goodies that the scientists needs on the instruments.

I have a standard instrument and you need to figure out what the configuration of the instruments are going to be - again are there any things that need to be ordered earlier than others. You need to know the depth the scientists likes the instrument, which may depend on whether the equipment has to be treated with anti-fouling paint and if it has a pressure transducer, will the pressure transducer take the depth.

It may seem insignificant but during the instrument preparations the cosmetic appearance of the instrument is important. I found that we do have a documented and a quite obvious instrument performance, due to some extent to the cosmetics because people seem to handle the equipment more gently and easier if it looks good. If something does not look good, if it is chipped and paint layered on top of paint I don't think people take as good care of it. Some of the equipment weighs 200 lbs and it is hard to carry around on deck anyhow. If it looks good then I think people to take better care of it .

Batteries for Equipment
I mentioned earlier that my moorings are normally two years with the capability of going to 4 years. The primary thing between 2 and 4 years is the type of lithium batteries. I have had very good luck with double "D" liquid cathode battery as opposed to the "Jelly Roll" type lithium batteries. The "Jelly Roll" do have a tendency, from what I have seen of practical experience, where the "Jelly Roll" type of construction does create internal shorts and the batteries will out- gas and create problems. I have not had any of these problems with these liquid cathode lithium batteries.

Lithium batteries do present an added problem though - it is a flammable solid and it is not allowed on passenger aircraft which makes shipping these things overseas more difficult and harder to get from point to point but if you have 2 year or 4 year deployments you have got to ship them! You really need to know what your local authorities regulations are with regard to lithium batteries as well as what foreign officials require. If you do plan on shipping, check with all the various countries involved and shipping lines to know what you will need for the batteries.
Disposal of the batteries does not seem very important but disposal is not that easy. You cannot just put them in the trash and throw them into the landfill and make it somebody else's problem. Take your time to find out what you need to do to get rid of them.

The instrument that makes up the majority of my instrument pool is the EG&G Vector Averaging Current Meter. It is a 25 year old instrument but really it has been for many years considered the "workhorse" of deep water oceanography. We have had very good luck with them and are routinely getting 90%-95% data recovery rates out of these. It does create some problems in that since it is no longer supported by EG&G and has not been for over 10 years, there are things which I need to do from time to time to order to make sure that I can continue to use the instruments. I need to check with my supplier from time to time and make sure there is not a component that is going to become obsolete. A few years ago I found a little integrated circuit that is no longer in that specific package configuration which meant I would have had to design a new board. I bought 400 integrated circuits that hopefully will see me to retirement.

Ordering Lead Times
It seems to be taking longer to get items and therefore I spend time on all my suppliers to see if they anticipate delays 6 months down the road because they cannot get parts now. I work quite closely with my suppliers and ultimately they work closely with me and are willing to help me out. If I know I am going to get funded for a project I will let them know as far in advance as possible so that they can start ordering parts for me that they will need in order to meet my delivery deadlines.

Memory Replacement
The SEA DATA cassette recorder which has been used for years in the VACM as well as many other types of oceanographic equipment. It was originally designed and started being used back in the early 1970s and I still use them today. There is a lot of other oceanographic equipment that still utilises the SEA DATA cassette reader. This (*example shown to the audience*) is PCMCIA data storage capacity which is a direct replacement for the cassette recorder and has been designed at Woods Hole with our engineers and is going to take us well into the next millennium with these instruments as far as data recording capabilities. I have got more information on these but I wanted to give you a view of what we are going from and to before I go much further.

I don't know how many of you are familiar with PCMCIA technology but this is what we went from - a typical cassette tape. A 300 foot tape which has the data storage capacity equivalent to about 1.2 or 1.3 megabytes. Depending on deployment length and characters on the instruments they can record data for 2 years. What we are moving to is the newer technology PCMCIA which is Personal Computer Memory Cards International Association which are credit-card size, just a little bit thicker.

These come in multiple sizes, the one I have here is 10 megabytes which is 7 or 8 times what a cassette case is. They are available up to 20 megabytes with the expectation that this will go up to 40 and maybe 100 megabytes. The problem is that you start getting into battery life at this time. I designed PCMCIA Memory to basically take the place of the cassette recorder using a 2 megabyte card so I have got more data storage space and I have not redesigned the battery. The instrument has a 5-wire hook up. They need a voltage to write data to them. If you remove the voltage from it, it is not volatile so once something has been written to this card it does not go. This specific card was flooded (*example passed around the audience*). I have recovered 80% of the recorded data from this card that was flooded. It has been washed, flushed out and reworked and if I had very small hookups and leads for these chips I am sure the rest of the data could be extracted. The non-volatility of this new memory goes a long way!

The cassette recorders magnetic tape was non-volatile as well but having to open up the cassette tape and wash 300 feet of cassette tape by hand gets tedious - getting it back in the cassette case is even more tedious but it has been done.

Some of the reasons for the memory replacement were the inability to obtain spare parts for the tape deck and for the reader. Both these instruments have not been supported for quite a while. The mechanical parts are not available. With the mechanical properties of the tape deck and the reader there were inherent problems such as tapes jamming, tapes breaking, improper installation of the tapes, something simple like the tape not getting between the capstan and the pinch roller. The instrument goes into the water for 2 years, it records data on the same spot for 2 years, you cannot recover that data.

We are trying to keep this equipment operating and the VACM has proven itself to be a very reliable recording instrument. We want to keep it that way and at this point we have not found anything that will replace it. We keep trying other equipment but when you have 90 VACMs in your inventory, you don't just put them out to pasture or retire them that easily as it costs a lot of money to replace 90 instruments.

In designing the PCMCIA memory we wanted it to be adaptable because I know about 8 different oceanographic instruments that have used and still use SEA DATA recorders. The recorder is a 5 wire hookup to the instrument - it goes in, you hook up 5 wires to the back plane and you're done. You have power, a ground, a data shift request, a shift register and your actual serial data (5 wires and you're back in business). The battery packs can be modified to take the higher memory of 20 megabytes/40 megabytes. Moving to lithium batteries you can probably go to 20 megabytes without a problem.

I would really like to see more implementation on my part of the PCMCIA memory and am moving in that direction. I am also hoping that our operation at Woods Hole, within a short period of time, will have these memory replacements available. It will be on a cost basis - for the labour, parts, etc., as we want to get into building these and selling them to other concerns to put into their equipment. It will bring funding into my operation as I need to have some outside funding and the little jobs that we do from time in order to help other people will help.. We are not a commercial outfit but the little bit of extra funding does not hurt.

Acoustic Releases

I still use the older EG&G 322 squib fire releases. Everybody has their favourite acoustic release and if it works stick with it!

Transmitters, Lights & Radios

The radio transmitter and the strobe lights are still being using to give you a little bit of false security (that warm fuzzy feeling when you go to recover a mooring). It is not as important as it used to be because with the GPS navigation today you are able to get back to a position a lot easier than you were 10 years ago when you had a 3-mile difference in positions of where you thought you set it and where it actually is. The one thing I do is rely on quite heavily is the ARGOS transmitters.

This is an ARGOS transmitter (*example shown to the audience*) that was developed at Woods Hole after years of using other types, we have implemented this. It is the transmitter that is currently used by me and is manufactured commercially by Seimac Ltd in Canada and is marketed for about $3,000 which is a lot less than all of the other ARGOS manufacturers. They are represented in the UK by Marine Environment Systems and Mr Richard Winterburn is the local representative. They supply the antenna plate and transmitter and it is then encapsulated into a glass ball. Kenton M Bradshaw and I at Woods Hole Oceanographic Institution have recently written a Technical Report entitled "Ten-Inch Glass Ball ARGOS Transmitter using Seimac Ltd. Platform Terminal Transmitter" (*Woods Hole Oceanographic Institution - Technical Report WHOI-96-07, July 1996*).

This equipment has saved 3 moorings for me this year. The ARGOS transmitter is meant to be put on the moorings - I put them on the top portion of the mooring to allow us to know when the top portion of mooring comes up. I know if something breaks down here, then this is going to come to the surface and this is what I am interested in. If this breaks and I don't have a transmitter on there, I don't know there is a problem to begin with. If that comes up then I know something is going on, so as I say I originally mount it to the top.

The ARGOS transmitter is now available with a GPS receiver which gives it extra added capabilities enabling you to programme the GPS receiver to set up a watch-circle. If the GPS receiver goes outside that watch-circle then it will start transmitting to ARGOS its position so you don't start getting ARGOS charges until it is outside the watch-circle window. They are also coming up with a system which will be a 2-way ARGOS, which you can programme from the beach and actually talk back and forth to your ARGOS transmitter.

One of the things I put on my moorings is a surface-acoustic transponder in addition to my releases. This serves two purposes:

1) Should the release not respond when I come back to the site, it gives me a second instrument that will allow me to determine if the mooring is still in place. A lot of times the acoustic releases may still operate correctly, i.e. release, without being able to talk back to you. So if you can determine that your mooring is there, it may eliminate some of the time need to conduct a search pattern for it and let you know that the release is still there.
2) It can also tell you that if part of the mooring is gone and at which point the mooring broke, so you know how much of the mooring you still have under water.

Moorings

You need to take into account what type of instrumentation is going to be used, do any of the instruments require any special hardware? You need to keep this in mind during your planning stages to make sure that you don't forget something or leave something on the beach. It could be as simple as special size shackles - you don't want to have to put in an odd size shackle in a mooring string, something that would be too loose for the mooring, something that is designed for a 0.5" bolt and all you have is 3/8" bolt or converse to that, something that requires a 0.5" bolt and all you have is 5/8" bolts which won't even fit. All this needs to be kept in mind.

Specialised Equipment - High Currents

One thing we do put on some of our moorings is a rigid fairing which clips to the wire and reduces the drag and consequently strumming, to improve the performance of the mooring under a high current situation. We do not usually put the fairings we use below 1,000 metres because what we are looking for is to reduce the drag on the mooring in the higher levels so that it does not get knocked down too far. In a high current of >50 cm/second, the mooring can be dipped to the order of 100s of metres. This can have a multiple impact in that if it dips too far the inclination on the mooring is such the current meter vane and other parts which are gimballed, are not gimballed further than 15E and also if the mooring dips too far you could be looking at a piece equipment failing because it has gone too deep. Most of our moorings are going in 4,000 metres of water and instruments are capable of withstanding the full 4,000 metres. We used an ADCP a number of years ago on a surface buoy. The surface buoy broke, the ADCP fell to the bottom and all we got back was a crushed pressure case. Therefore, if you are going to be putting something in deep water, plan for a full ocean depth and don't put a shallow instrument in a shallow position on a deep water mooring. The fairing many times will make a difference on the order of 8E - 10E difference in the tilt of an instrument.

Scheduling Deadlines

Allow yourself leeway - know when you equipment is going to be delivered, both for the cruise and for your daily operations, don't ever give a supplier your sailing date. I don't know how many times I have had somebody say “when are you actually sailing”. If they know that forget it, your not going to go to sea with it. Give yourself a couple of weeks and give yourself some time to react to a supplier not being able to delivery. Get to know the ship you are going to sailing on - what navigation it has, what it has for radio receivers and direction finders if you are going to need them, more specifically, the frequencies of those radio receivers and direction finders. If the ship people say “oh sure, we have a radio receiver” what if it’s not the right frequency? What they have for winches, what they have for cranes any other specific equipment. If they don’t have it, take a look at your own operation - do you actually need it? Is it something that is a must for the operation. Can you get around it? Sometimes you can, sometimes you can’t. If the ship says it has it, try to find out what kind of condition it is in. Just because they have a winch doesn’t mean that it is operational. It doesn’t mean that it can haul the loads you are looking at, so know what you are working with.

Ship Loading Logistics

Try to let the scientists coming off the ship have enough time to clear the vessel of their equipment before you are ready to put yours on. Most ships will give you a couple of days and this helps - you don’t want to be tripping over people or leave something on board. Try to keep from doing two or three operations at the same time - left the people get off before you go on.

It is possible to reduce the cost of your shipping by negotiating with the shipping company prior to your actual shipping dates a rate for your shipment. I shipped a container home from Rio de Janeiro a few years ago and it cost approximately $7,000 to $8,000. When I got home I found out from my shipping broker in the US that if I had filed for a rate with him, it would have travelled as a different commodity and I could have shipped the same container for about $3,000. So it is worthwhile checking with your shipping company to find out what you can do to reduce the costs of shipping containers. It is not quite as easy as that when it comes to air freight - it is more rigid, but there is a little bit of play if you have a good agent who will represent you.

You also need to know what ports you are going to working from and if you need to do work on your equipment in a foreign port prior to the ship sailing. One of the most important things is to have an Agent to represent you. I have had quite good luck over the years using the same agent as the ship uses - they are attuned to it and they are getting money from two sides - both from you and the ship and they are a little more willing to work with you. You possibly may need to set bonds for the equipment. Usually a shipment is consigned to the Master so if you need to get your hands on it, there is no way if it is consigned to the Master you have to wait for the ship to come in, but there ways around this and you can conduct your operation prior to ship arrival with pre-arrangements. You need to know where the operation is going to take place and accomplished and know where you are going to work. Voltage requirements for the area - do you need to travel with a transformer in order to change your needs for your specific operation.

Mooring Design

When designing moorings you have to think about the depth of the mooring, where it is going to be located - is it on a steep slope which requires specific anchors or other equipment, and what are the currents going to be? What is the maximum current that you expect? Not only do we design our moorings for a design current profile, we also design them with a maximum current profile in mind. If you expect a 25cm/second current and the mooring suddenly sees a 75cm/second current, will the mooring survive? It may get knocked over to a point that it is past the workings of the instruments, but usually I try to keep the inclination to below 15E. Are any special requirements needed - is it a bottom mounted package, is it a near bottom mounted package, etc?

The surface mooring is a tried and true kind of technology which we have doing for years, we have very good luck with these and we lose very little equipment and now thanks to the ARGOS, if something does come to the surface, we have had very good chance of recovering it. Surface people are more interested in the upper portion of the water column whereas the subsurface people are interested in the overall broad scale of the water column. The surface buoy needs to be more robust and the wire needs to be more robust. A surface mooring has an inverse catenary which is basically a wire nylon termination point. This has had very good success rates over the past couple of years in mooring survivability. Some standard moorings do not have that inverse catenary - you have a wire/nylon termination and when there is little or no current, the wires at the bottom portion actually dip further than the termination of the nylon. We have had problems over the years and the answer is that with nylon/wire termination you have shackles and one of the problems was that the cotterpins were snagging the nylon. By taking about a 15 metre or 20 metre section of that termination, we now wrap the termination and coat the nylon with a tar or something that will harden on the nylon to prevent any lose cotterpins snagging the nylon and cutting it. We have had very good luck over the past few years and we now have 8 to 9 month survivability on a deep water surface mooring.

This would be what the mooring would look like with a 25/30cm/second current (*Fig. 9*). With a standard mooring you do have a bit of a watch circle. With the inverse catenary our watch circle becomes larger and what happens is that you have a polypropylene line with flotation so this mooring even in a slack current regime, is designed so that it will bend over your termination between any wires. This allows for any possible problems with terminations between nylon and wire from happening. You do have flotation in this area, so that this is meant to be a catenary which is planned, whereas the other catenary you saw was not planned but happens after a time due to the stretch of the mooring. With a current applied to that, you can see the watch circle has increased quite a bit but as long as you plan for it, you can live with that (*Fig 9*). The inverse catenary has worked very, very well over the past few years and was recently used quite successfully in the Arabian Sea experiment with our Operation Group at Woods Hole and they had a good success rate with that.

This is our standard Mooring Design that we give to David Simoneau and the Rigging Shop so they know what to use as far as what wire we require (*Fig. 10*). We are very specific about how long the wire is and what kind of wire or chain it is. We go one step further than with the surface moorings and we tell them what kind of terminations are going to be at each intersection. This is dependent upon what the loads will be, and the instruments are set up to accept so you need a good detailed list.

Another type of surface mooring that we use would be a shallow water, where we do not have the inverse catenary (*Fig. 11*). This still have a bit of a watch circle because rather than a catenary everything is quite rigid all the way down and we actually have a piece of ground tackle and swivel. We don't usually use swivels on our subsurface moorings but we will use them on surface moorings. If you have a wave test buoy that is meant to have a watch circle, this may be what we use for that, where we have a subsurface sphere which will keep the mooring rigid and the wire or rope has floats on it so that it will not get tangled. This is meant to follow the waves and can't be too rigid - it has to be able to float and bounce about.

Bottom Moorings

In shallow water we have come up with this (*Fig. 12*) which is a frame we have designed which is meant to be basically trawl proof - it sits very close to the bottom like an Acoustic Doppler current profiler. The profiler actually sits inside of this and has to be anchored to the bottom. It is very low profile and dragger resistant, not dragger proof! You have releases and instrument packages inside the frame.

This seems to do the job when people put things out in shallow water and they actually get them back quite successfully. What happens is that once the package is released the armed portion only comes to the surface to give you the recovery portion (*Fig. 12a*). It is rigidly mounted to the bottom anchor or frame, so that once you recover that, you then recover your bottom package.

Wire vs Kevlar

One of the ideas in the beginning was that by using Kevlar we could reduce the flotation for the buoys - this worked quite well. Kevlar does turn out to be about the same price as wire rope. It was thought that Kevlar would be a good replacement for wire rope, but in using it for quite a few years, we did stop using Kevlar and went back to our wire rope for 4 basic reasons.

1. The Kevlar was more susceptible to fish-bite and we have documented cases of experiencing fish bite down to 2,000 metres in the Atlantic. It is somewhat shallower in the Pacific but I don't know why that is, but fish-bite does happen down to 2,000 to 2,500 metre level in the Atlantic.

2. Reusability - It was thought that because it is not a wire that will corrode or rust it could be reused. This really is not the case - Kevlar can be reused if it is reused immediately, if it comes out of the water and goes back in wet. If it comes out and has a chance to dry out, it will actually develop salt-crystals inside the Kevlar fibres, cut the fibres and degrade the strength of the Kevlar.

3. Kinking of the Kevlar - In order to maintain a uniform diameter to the Kevlar fibres, the type we use was actually encased in a nylon jacket. However, the jacket was very tight and did not go across a sharp corner very easily and it would actually kink. As soon as it would

kink, it would damage the internal Kevlar. If you get a twist in there and have to undo the twist, to get it straight again, it may look fine, but the kink does cause significant decrease in the strength of the Kevlar.

4. Splicing terminations - This is much more labour intensive. The wire ropes we terminate with a cold swage technology which is a fitting that you put on your wire and with a 500 tonne press, we actually press the swage on to the wire. The Kevlar on the other hand has to be spliced or braided something very similar to a 'Chinese finger' where you put a hard rigid eye on the Kevlar and you have to braid it around and the splice ends up being about 2 0.5 metres long. For a wire it takes about 5 minutes to do a splice - Kevlar over an hour to do each splice.

Hardware

We have just discovered method called "Shot Peening" which will increase the life of a shackle (*"Cyclic Fatigue testing of Surface Mooring Hardware for the Arabian Sea Mixed Layer Dynamics Experiment" - Woods Hole Oceanographic Institution - Technical Report WHOI-95-16, December 1995*). This report was generated by Richard Trask and Robert Weller of our Upper Ocean Processes Group because of the Arabian Sea Experiment. Primarily what they found was a standard off-the-shelf galvanised shackle comes with a surface stress incorporated into it. The process of "Shot Peening" is something very similar to sand-blasting, where you actually blast the shackle, but rather than a sharp-edged grit like sandblasting - this is a very uniform little round ball which you treat the shackle with and it reduces the surface stress, and therefore the piece of equipment is less susceptible to fatigue. You can therefore increase the life on shackles and so forth from a 200,000 cycles of stress and no-stress, up to 1,000,000 cycles of stress and no-stress. After something has been "Shot Peened" you cannot galvanise it - the regalvanising will reintroduce the stress into the shackle so you have to find some other method to prevent corrosion on the shackles.

For years we were using this shackle pin on the top, where the end of the shackle is actually under cut where the cotterpin goes - we are getting a lot of cases where this nut would come lose - it would back off to the cotterpin and in a lot of cases actually back right off the shackle, even with the cotterpin in place. We have now gone to leaving the threads all the way out to the end of the shackle pin. In this case here (*see report referred to above*) , you can see how this cotterpin was bent over but with a few wrenches we were able to back that nut right over that cotterpin. With wrenches here, we bent the cotterpin but we were also starting to bend over the edges on the nut - this will not back-off with the threads all the way out to the end. So we have now gone to changing our shackles from the standard safety shackle with the under cut on the end, to having threads go all the way out to the end of the nuts. We have not had a problem with backed-off nuts since this.

Deployment (*Figs 1 to 8*).

The deployment operations are pretty standard but will vary from ship to ship. If we have equipment that is very close to the buoy, we will actually put the equipment over the edge prior to the top float. We will continue paying out more equipment until we can get to a point when we are comfortable that when we release the top float, we won't have everything come in on us because with the weight, it will tend to draw back to you. We will then get ready to put the buoy over the side, again everything is pre-connected up to the winch, it will go over the stern and back to the winch, ready now to get the equipment over the side. A quick release hook is what we use on the buoy so that once this is in the water we can trip a line and let the buoy hook go away. Never drop the buoy from 3 feet above the water - let it get into the water before you trip the quick release hook. People can get anxious and then suddenly it is coming down from 5 feet above the water and 'bang' you have to replace the entire instrument suite. It will drift aft, so you continue allowing it to drift aft and in 4,000 metres of water you have 2 or 3 miles out behind the stern of the ship. Most of our moorings are designed with enough flotation down by the release to float the entire mooring, so if it breaks and everything falls to the bottom, we have enough flotation at the back-up flotation down deep, to bring everything back to the surface.

The final thing is 'anchor away' - the anchor free-falls. On a surface mooring these anchors many times are 7,000 to 8,000 lb anchors - we use a cast anchor rather than railway wheels. We also use a baseplate on the bottom of these on a slope region to help dig in. I attended the ONR/MTS Buoy Workshop in March 1996 and the abstracts of that might give you contacts and people's names should you have further questions about the above. (*Interested readers are recommended to contact WHOI for further information about this publication*).

(*Numerous other illustrations were exhibited and are included as Figs. 13 to 20*)

Interested readers are recommended to contact WHOI for further information about any of the publications mentioned in this section.

Questions

The chairman decided, at this stage, that questions for Mr Worrilow would be held until after the next speaker's presentation since they were speaking on subjects closely related to each other and both presenters would be able to respond.

Mr Richard Winterburn - Marine Environmental Systems (MES)

MES do three major areas:

We offer straight consultancy in marine related IT. We take hold of projects, carry out a lot of strategic marketing for people who see opportunities in the marine field with their instrumentation and systems and don't know how to penetrate it and we help business develop in that area.

We also look after other people's systems - software and hardware. On the software side particularly managing large quantities of environmental data and displaying it and that has taken us into the realms of electronic charting and most recently into electronic publishing. Turning data into more usable forms, so that the world can get access to that data.

Instrumentation
We look after the instruments from SEIMAC and both in the UK and into Europe. SEIMAC - this is a name that has been developed from Joe SEIler who is the scientist originally from Bedford. The MAC is Hugh MACpherson who was a Canadian Naval Captain and the two of them got together about 16 years ago and set up SEIMAC Ltd based in Nova Scotia. Their work is almost entirely custom-built systems to meet scientific objectives in oceanography. Increasingly now the systems they are developing are coming off the shelf, but any of the systems you have seen or heard about this morning - SEIMAC's real business is in tuning those systems and having them integrated into other people's systems. Woods Hole is the perfect example where we have supplied purely components of other systems which we would have integrated, but they themselves have done it. The same is true in this country - Proudman Laboratories have our system inside the Myrtle project - they have done their own integration.

We also supply complete buoys, drifting buoys, moored buoys, etc. through SEIMAC. BOT is Brooke Ocean Technology, again based in Nova Scotia - more involved in handling systems for deployment of such things as AUV's and more innovative navigational instrumentation.

ARGOS
The ARGOS System is a global satellite-based location and data collection system, dedicated to studying and protecting the environment.

In the future systems that you will come to use to do the sort of job ARGOS is used for today, that will not be their prime objective. ARGOS is really dedicated to the environment but it is a piggyback system and sits on board the NOAA spacecraft. It is a system that has been operating for quite a long time and through successive generations of spacecraft. The ARGOS system has been able to piggyback by agreement between the organisation which manages it, CLS and NOAA.

In essence you have a commercial organisation riding on the back of a US environmental satellite. The actual space segment as such of the ARGOS system is normally just utilising two satellites. Occasionally with the new generation satellites you actually get three and we are in that phase at the moment but normally it requires two polar orbiting satellites and when we start to talk about future systems, this is where we start to see the limitations of ARGOS. They are polar orbiters - there are only two and in the simplest terms, your transmitter does not see the satellite all the time. There are normally two satellites and three principal ground stations. So not only don't the satellites see the transmitter all of the time, they don't see the ground station all the time either.

You also have two principal ground processing centres, although there are some secondary ones in other places in the world, and they are the point where the data initially comes down and then is distributed out to the end users. It is a store and forward data relay service nothing more. The messages are received from the transmitters and held until the satellites pass over the ground station. We heard earlier this morning about some of the problems with ARGOS - information about the ARGOS data coming in and sitting in an in-tray. The problems, in principle, with ARGOS are really in the ground segment if there have been problems, other than in an operational sense in the way the system has been put together. The transmitters don't see the satellite all the time and because of the configuration of two polar-orbiting satellites, it varies with latitude. Obviously, if you are sitting at the cross point of the orbit on the poles, you will see the satellites virtually continuously. If you are on the Equator then far less, so the amount of time available to you to see those satellites varies with latitude. Something between 6 and 28 times a day.

The data that you are allowed to send through the system is controlled. Part of SEIMAC's role in this is actually to help you manage the data stream. ARGOS constrains it to 256 bits but there are ways to increase this. A good example of this is on the Myrtle project for Proudman here in this country. They are collecting data for up to 5 years on the seabed. The data then come up to the surface with the sphere in which the instrumentation is held and we will put back about a megabyte of data. Then that data has to be packaged together and sent back with a series of passes of the satellite. Another great constraint with ARGOS is because there is no 2-way communication, there is no confirmation to you that the data have been received and there is an in-built redundancy in the system that continually sends the same data, until the package that is being sent is changed, so there is a tremendous amount of redundancy. It is in fact a major limitation because you could, if you knew the data had been received, be actually sending more and more data. These are some of the facilities which in the future are going to go which I will discuss later.

Getting hold of the data from ARGOS

Active You can actually go to ARGOS electronically and grab your data in a number of different ways. Those ways are increasing and now you can even use E-Mail. You go with your modem, dial in and grab the data.

Passive You can also sit and wait for that data to come to you, either automatically or else by sending a piece of paper and it comes out on a printout and is sent to you. This uses a prearranged programme which you sort out as a user with ARGOS.

These are the normal ways of getting hold of the data and this is for any ARGOS platform. Most of the work that SEIMAC are involved in, is not in moored platforms but in drifters, so that you have any number of those scattered around and the data are coming out of the programme from Toulouse or from the US either in an active or passive sense.

ARGOS also operates special programmes for monitoring, which Scott Worrilow described as a user this morning, both for subsurface and for surface moorings. They know the ID'S they are looking for but in fact the data is not coming from those platforms at all - it is a subsurface mooring and it doesn't come until it actually comes up to the surface and what ARGOS have is a management programme to watch until that transmitter starts to transmit and until that time nothing is going on at all. Then when it starts to transmit, they then send a message which is very simple, saying that the transmitter has started to transmit at a certain position at a certain time. So it is a strict monitoring service. All of the data included in here are straight ARGOS data, you have to rely on the manufacturer, and SEIMAC is only one of those, to include other systems.
If you then want to actually increase the complexity of that and build a system as Scott Worrilow described earlier, you can build in your own monitoring service and have the data recorded, for monitoring locally, (SEIMAC are now getting involved in this sort of project) and having a GPS receiver actually on the buoy and monitoring the position on the buoy intelligently with the unit, until such time as the buoy has gone outside the watch circle. Only at that point in time starting to transmit and hence starting to incur additional ARGOS charges. These monitoring programmes can be left entirely to the ARGOS systems, in which case they tell you when things are going wrong or when things are moving.

SEIMAC programmes are about building and modifying electronics to suit the end user but increasingly these are becoming off the shelf units. There is the standard transmitter which is known as the Smart Cat PTT -very small, low powered, low cost. Basically there are two boards in it, a controlling board and the RF unit. The board has then been expanded on the GPS Cat, with the same principles, with ARGOS components, a controlling board, and there is also a Trimble SV6 GPS board put in there. Now you have the ability to use ARGOS for transmission and GPS for positioning, as well as ARGOS for positioning. Again this is into a small low powered unit. There is also, on both of these, the ability to interface to a range of sensors so you can put on your thermistors, salinity sensors, etc.

We are now moving into far more rugged casing and a fully off the shelf system because we are actually gearing this now into very large numbers. A large order for PTTs is about 25 to 30 for a drifting programme - in total ARGOS have at the moment about 2,500 PTTs. As we move on in capability with the satellites, we are actually looking at programmes where we are going to be monitoring 10,000s, 100,000s probably 1,000,000s of assets - we are moving into the world of asset tracking. You are doing asset tracking now or asset monitoring, in future it is going to be much more generalised and so we are looking at more robust systems, because the users don't want to understand the technology involved, they are only concerned with the data that comes back. When we look to the future we are going to be looking at new satellites and new management techniques to handle this, which in a way will sideline the ARGOS system but they are a commercial organisation so they are having to do things to combat what is going to happen. They have announced a programme of improvements to the ARGOS system and the three areas that they clearly need to improve, not just to counteract the outside world but in order the answers the requirements of their users are:

1. Greater sensitivity - which means lower power, so for the same power supply you get longer service from those systems.

2. Greater bandwidths - so you can send more data.

3. Two-way communications, which is probably the largest single requirement at the moment which ARGOS can't satisfy. When you receive your data you can't say anything to the transmitter or platform. You can't change things, etc. The two way communications that are required will give you that capability.

There are going to be many numbers of satellite systems that are going to offer the same service. ARGOS is a low earth orbiter which means you can use small compact autonomous systems based round these sort of transmitters. What is happening now is the emergence of other commercial services and these can involve complete constellations. They are:

ORBCOM (The Orbital Science Corporation) which has now grown from a very small corporation into a very large organisation. They are now building a multi-million dollar business. Their satellites are going to be launched from aircraft into space in clusters of 6 at a time and when we talked about ARGOS being 2 satellites to give you the data and communications you need , ORBCOMM will have 34 satellites. This will give you immediately, visibility of satellites at your terminal at all times and also the ability to communicate that data virtually in real-time back to you. You will be able to have 2-way communications in virtual real-time with your platforms.

STARSYS programmed to have 24 satellites and this has just been taken over by General Electric in the US, with lots and lots of cash going into the programme.

IRIS is a European founded programme to get into the same business.

SAFIR is an Eastern European programme and they are already selling systems which will utilises 2 satellites that SAFIR have flying. Proudman have already had their hands on one of these systems.

What these services are going to offer firstly is a choice and all of the things which we need from ARGOS. Greater sensitivity, far more bandwidth and millions of platforms and they are also going to offer 2-way communications.

ORBCOMM are going to be putting 34 satellites up - they have 2 flying at the moment to allow people to get the system piloted and to get their data working and to get the ground infrastructure going. They will offer 2-way communications and they are saying conservatively more than 3,000,000 platforms or maybe vastly more. They are putting 6 more satellites up in February/March/April 1997 and their target is to have 34 flying by the end of 1998.

Another great advantage of these is that they are strictly commercial and when I looked at these figures last week I asked if I could make them public and they said 'yes'. I was staggered. You all know the charges you get from ARGOS and you have to push them into your budgets. You are looking at a totally different world when you start to look at these newer satellite systems. There will be an initial connection charge of about $35, they will then charge a flat rate per month, much like ARGOS does per day, of $15 and then they are going to be just like a commercial telephone company - $0.07 (10p) for 160 characters and there will be special 'deals' because they are in this business to win and when they see the other satellites. This will probably be the first large scale operational commercial satellite organisation but hot on their heels will be the others and I am quite sure that the first thing that will start to tumble is pricing. This is their starting point and I am astonished.

As far as MES is concerned, we will continue to market the SEIMAC equipment over here and SEIMAC have already moved very strongly to take advantage of these services and have recently been awarded a $2,000,000 contract from the Canadian Space Agency to turn this technology into 2-way technology. It is partly funded out of SEIMAC and partly out of the Canadian Space Agency. The object will be to end up with a 2-way transmitter/receiver. The idea being that we will look towards a modular system where the boards can be slotted in or taken out to suit the particular technology. At the moment all different technology is being used. One single receiver will not at the moment handle the other systems - how we'll deal with the other satellites I don't know yet. As far as ORBCOMM goes, we will have a system up and ready by the time that constellation is complete - about 12 months from now.

Our aim therefore is still to offer the ARGOS service and for many applications I think ARGOS will continue, as they are responding technically to the challenge. Equally, we must offer the ability to include the use of ORBCOMM or any of the other satellites services with our tracking systems. You have to realise that their target market is not you or us, their target market is general, commercial, global tracking but the real interest to you is in the large numbers. They are not talking about selling 25, they are talking about selling 25,000. They are talking about putting trackers onto containers, onto ships, onto cars, onto rail wagons. This could have a down-side for the ocean community but it can also have an upside. The upside is in things like costs, technical capability, etc. The benefit for the oceanographic community is going to be tremendous. You are going to have a lot of facilities you have not had for a long time available to you and at very low cost.

Questions for Scott Worrilow and Richard Winterburn

K G Robertson (RVS) to Scott Worrilow (Woods Hole)

Q. You had some very impressive diagrams of mooring designs, lists of types of termination, etc. How much do you use computer programmes to assist you in this? Are there good ones, bad ones, can you recommend something?

A. The moorings are almost completely designed by computer programmes. Subsurface moorings use an old programme that has been used for years. There are a few other versions around, there is a programme called NOYFB that has been around for year. Jim Hamilton at the Bedford Institute has a modification or newer version to that. There are a couple of different mooring design programmes around. The pictorials are from an ACAD programme used to make the actual diagrams for the moorings.

K G Robertson

Q. Does anyone else use a favourite computer programme to do this or any advice for people?

A Hartling - Bedford Institute, Nova Scotia

A. I work with Jim Hamilton. He modified and calibrated our mooring model and uses it extensively. Without it we could not put moorings out.

K G Robertson

Q Are these programmes freely available? Can you buy them or obtain over the Internet?

Scott Worrilow

A The designs for the surface moorings is something that is sold by an engineer called Henry Bertou? in the US. He is very well known for his contributions over the years to oceanography. NOYFB is available but unfortunately the documentation for it is horrendous. It is one of those programmes that you have to use for a couple of years before you become somewhat proficient and the key word is 'somewhat'. As stated previously, I would like to help people out and if you would like me to try to get you a copy of a list of people to get items from, I can definitely find out.

Dr Takeaki Miyazaki - Nippon Marine Enterprises Ltd, Japan

Q What is the benefit of the inverse mooring systems compared to the towed mooring?

Scott Worrilow

A The inverse catenaries have proven quite recently to perform very well and have increased our life of deep surface moorings, not to be confused with shallow water moorings. Shallow work is completely different from the deep water. The inverse catenary has decreased the number of failures we had due to hardware stresses in the wire/nylon termination. There are so many aspects to the surface moorings and their life that any one specific item can not be coined as the saviour of surface moorings. It is a combination of everything but we have found that the inverse catenary greatly reduces the amount of failures we have seen from the wire/nylon termination. It reduces quite significantly the number of failures we see due to stress fractures, because you are not having the constant tugging and jerking. It is more of a free drifting mooring.

A lot of the improvements have come from this. It has been difficult to put a surface mooring in deep water and have it survive more than 3 or 4 months prior to this. We did a project off Iceland in the late 1980s, as part of the Marine Mixed Layer Experiment, with a standard mooring that lasted 70 days when it was meant to be in for 5 months. With the inverse catenary technology we are now successfully mooring things for 7/8/9 months and these changes have happened within the last 5/6 years.

R Groenewegen - NIOZ, Netherlands

Q Could you inform us about corrosion and material choice. You have a long lasting record with instruments, you have been using them for over 25 years and I would like to know if these are the same instruments, have you had them rehoused in this period, are they still as new?

Scott Worrilow

A Almost everything we have has good secure coatings of some sort of epoxy based paint in order to protect it. This is over the top of any anodised hard coating. We make sure there are no holes or nicks in the hard coating. If you get a hole in there we take a small tool and etch out any corrosion that may be beginning under the hard coat, because if you do not correct the problem immediately, the corrosion will actually extend in under the hard coating and start to lift the hard coating up. So if you don't correct problems of nicks in the hard coating, immediately it will wander, but the big thing is to get a paint coating on the hard coat. The hard coat was never meant to be fully submersed in sea water for long periods of time by itself. It is meant as an aid to help the outer surface of the aluminium but I don't think it was meant to be immersed in seawater.

As far as corrosion of other items such as chain, wire, shackles, we are very in tune to making sure that we do not have dissimilar metals touching. If we have a stainless touching a galvanised, we make sure we have nylon or bushings making an isolation between the two dissimilar metals. You can go overboard and have too many anodes but this is trial and error on your specific application. We have had no problems with galvanised wire rope; our wire ropes are jacketed in a plastic. We recover the wire after 2 years, strip the jacket back and it is just as clean as the day we bought it.

We do sometimes run into problems with the cold swage terminations because a 3x19 strand wire has gaps in among the layers, so we make sure that we fill those gaps with a filler wire, so that when you swage it you don't have any voids in there and that improves the swage. We also put a strain relief boot on the swage for two reasons:

1) to protect it from the elements when it is out of the water
2) it also acts as a strain relief when it is in the water so that you won't get any sharp bends.

J Schilling - NIOZ, Netherlands

Q How many times are you using your wires?

Scott Worrilow

A Because of the plastic jacket on the wire it is impractical to inspect the entire length of wire after deployment. We feel the project it is important enough that we buy new wire for every deployment.

Once the wire has been used once it does not go back in the water for science.

J Schilling - NIOZ, Netherlands

Q What is the difference between your weight and your buoyancy?

Scott Worrilow

A We use a cast iron cylinder that we can have cast to our requirements. If you get a typical railway wheel it normally weighs about 600 lbs but a weight about 1,500 lbs, that is basically solid pig iron, is the same size as a typical railway wheel. You can double or triple the weight of an anchor by using just solid cast steel where you don't have all the cut-outs the railway wheels have.

The subsurface moorings are designed with a 2,000 lb. positive buoyancy at the top float. Our design on the moorings is that when the mooring is actually in place we try not to exceed about 50% to 55% of the breaking strength of the wire in buoyancy at any given point of the mooring. We will actually add flotation at various parts of the mooring down through the mooring column to change how the mooring is acting. So if we put an instrument on, or we have a 1,000 metre shot of wire, we will add flotation in order to bring our buoyancy back up at various levels. As far as a deployment tension, our programmes will also calculate a deployment transient tension on the moorings, where once you kick the anchor over and the anchor is pulling everything back through the water column, what are the expected wire tensions to be seen on the wire. For our deployment transient, we try not to exceed 75% or about 2,700 lbs. on a 4,000 lbs. breaking strength wire.

Denis Heiden - Cousin Freres

Q 1. Reusability **-** You said that if you allow a Kevlar or Aramid mooring line to dry out, you get salt crystals forming and that those salt crystals will probably chew up the Aramid strength member when you redeploy. What I would like to know is if you do let a line dry out and before redeploying it, you wet it with a hosepipe, would that dissolve the salt crystals and therefore not damage the line?

Q 2. You stated that Kevlar is much more labour intensive because of the splicing, etc. Would you agree to use a mechanical termination such as a barrel and spike termination, which can be put on in about 5 minutes?

Scott Worrilow

A If you wind up the Kevlar on to a wooden spool and then just let it sit for a while and you unwind it onto another spool washing it on the way, I believe you would still be getting movement in the Kevlar in the transfer from one drum to another and without absolutely knowing what some of the physics are behind that, I would expect that you would do as much damage from that transfer from one spool to another, trying to wash it as you would in redeploying it. You could try washing it as you recover it, but again this is similar to a synthetic nylon. After it has been in the water you recover it and it has stretched quite a bit, so it is not as easy to work after it's recovered. It will already have the distresses and I think it would kink much easier and you would see a lot more possible failures from kinks that actually happened during recovery that you try to straighten out and just put back on the drum.

As far as the terminations are concerned, at Woods Hole we are very conservative about what we put in our moorings and make sure things do go through a very rigid testing period before they go into the mooring for the first time. Kevlar is an excellent product and I don't want to discourage anyone from using it **-** it is definitely a useable product. What I found for our application is that the wire rope serves us better.

K G Robertson - RVS

Q At RVS, we routinely use GPS and we are starting to use differential GPS rather more now. Ed Cooper **-** could you tell us how we implement DGPS, particularly when we are away from shore as I have been surprised in some discussions of how little is known about how we go about doing this and what sort of coverage there is available.

Edward Cooper - RVS, SOC

A The differential GPS service that we provide on the Royal Research Ships through NERC is simply a bought-in commercial service and when we are around the UK coast we provide the service via radio beacon technology, i.e. lighthouses. The US is also set up with lighthouse beacons around their coasts but once you get about 150 miles out they are not much use and the only way to go then is to go to the commercial suppliers. There are various grades of these and some have products that have come out of the back of a garage and others have products which actually work for you. One of the main elements today is what sort of Satellite Communication system you have got to fit with these commercial services but if you go to a major player in the commercial services, they will give you a good product, although it costs about £120 to £130 per day depending on how many consecutive days you wish to use the system for and how many days you rent the kit. We have had some experiences recently where we have wanted to use the system for 6 days in 6 weeks and they are not too keen to let you have the equipment for 6 days in 6 weeks and only pay for 6 days of usage - quite understandably - and they have now tightened up on their pricing structure.

Some of the American UNOLS ships have access to P-code receivers. In the UK we have attempted to get access to P-code receivers but have met with a sharp rebuttal from the Pentagon to say that the commercial services are far better and why do we want to pursue it? Well the reason we want to pursue it is that once you have got it, its free everyday, rather than the commercial services that are expensive. However, the commercial services actually give you much better precision.

K G Robertson

Q I believe the other term is "Selective Availability" with the GPS system or 'dither'. I don't know if anyone has experienced this but is there any move to take away this source of inaccuracy?

Edward Cooper

A There are techniques for getting away from it but it means more expensive receivers and more antennae.

K G Robertson

The history is that if you are in an area of international conflict, such as the Arabian Gulf at present, then the GPS equipment is at it's most accurate and not disturbed.

Edward Cooper

You have to understand that the system has been put there for a military purpose. There is a large lobby within Europe to put up subsidiary systems and we would then no longer have to rely on GPS or we could consider combinations of GPS and GLONASS. Until those systems actually come alive, you are reliant on the decisions of the Department of Defence.

With regard to the low orbit satellites from ORBCOMM and other companies, there will be developments in the future with regard to mobile telephones - the development of these transmitters is so that they can track lorries and containers. Soon there will be Cellnet coverage around the world via satellite and a development of that will be navigation. In the UK, differential signals are put out on Classic FM and when you are driving along you hear Classic FM, you don't hear the demodulated signal but if you have a decoder they can tell your GPS position within metres. Colin Beatty of ASHTECH told me 5 years ago that every time he drove up the M1 (*a major motorway in UK*), the GPS antenna was on the top of the car and he recorded the route up the M1 and having done that repeat route umpteen times, they could position where the M1 was on a map and hence you could get into the business of being able to steer cars!

Richard Winterburn (MES)

I have heard a whisper that ORBCOMM, which will nominally be operating at around 140-150 MHz, will actually have a 400 MHZ channel and they say for a "GPS like signal". Clearly they have that capability if they have that number of satellites up there, then you could actually think of completely bypassing GPS.

K G Robertson

Q Navigation and recovering moorings. We have mentioned GPS and differential GPS and we have just mentioned P-code GPS and we know that some of the operators in US do have access to the P-code receivers. Do you have any direct experience of their benefits or problems?

Scott Worrilow

A GPS in itself is a great advance from the days of satellite "Transit" navigation. How close do you want to get? It used to be a joke, you are always looking for that magic little white "X" that's floating out there on the water where the scientists want the equipment but now I try to put it as close as possible but when I am dropping an anchor off a ship, there is a 10%-15% fall back of that anchor and how precise can you be as to where that mooring position is, when you are dropping the anchor and have takes 45 minutes before the anchor hits the bottom?

I think what is commercially available from GPS is probably close enough for most everybody's applications unless you are working in extreme shallow water and because of the array you are putting in, you need to have more precise positioning. DGPS and P-code is all well and good but for my applications, in my experience, GPS is about as hot as we need it right now and even though it has been dithered during the past couple of years and that has reduced it's precision, it is still a lot closer than it was 10 years ago.

Edward Cooper - RVS

What is probably more significant for the people putting down the moorings is the bathymetry of where they are putting these moorings, which is far more important than precise navigation. If you can go and do a multibeam survey, the swathe map of where you are going to put the mooring is probably more benefit than going to 'X' which is precisely known and putting the mooring there?

K G Robertson

Q So far everything said about moorings has concentrated on designing, putting them in the water and recovering them, choosing the right materials and choosing the right instruments. We all have to admit that sometimes we lose things, for all sorts of reasons. Sometimes they are not in the position where we expected them to be, sometimes a part of a mooring is there - for all sorts of reasons perhaps - the design not being correct, perhaps there has been normal commercial fishing activity and we have been in the wrong place.

What are the techniques for recovering these things if we lose them? There is the ARGOS system if something floats to the surface, then with the ARGOS beacon on we can find out where it is and we stand a chance of going back to get it. Sometimes, we have in our experience, moorings that don't move, they just decide to lie on the seabed - what do we do then? We are beginning to think that possibly the Remote Operated Vehicle (ROV) is a tool that we can begin to experiment with for shallow water work. We haven't tried this yet as it is a very expensive process to put into operation. Does anybody have this sort of experience or thinking the same way?

Sven Ober - NIOZ, Netherlands

A Regarding recovering moorings that are lying on the bottom after losing subsurface floats, I can say that we had this problem several times in the North Sea where we had a programme and when this happened we could recover them every time with a ROV that we had hired and it was worth the money and within half-an-hour it was on board again.

K G Robertson

Q We have been investigating this but we haven't operated the system yet. Were you able to make the ROV recover the equipment or just to attach a line or just to locate it? How far could the ROV help you?

Sven Ober

A They go to the spot where you think it is and the ROV is then lowered on a line - it is hard to interpret it on the screen but there is an expert on board to operate the ROV and he says OK - there it is - they put a hook on it and that's it. It is very simple.

K G Robertson

Q Can I ask you - is it cost effective? Is it worth the money that you have to pay to hire the ROV when you compare it with the return of equipment and recorded data?

Sven Ober

A In these cases it was very cost effective. We had a "friend" price!

K G Robertson

Q Can you tell me in what depth of water this was?

Sven Ober

A 44 metres. The most remarkable thing was that the mooring was covered by sand, the subsurface float had disappeared and the line with the thermistor string was covered but the operator could interpret it on the screen without problems within 20 minutes. I thought we would have to make a grid and a survey.

K G Robertson

Q You were able to say exactly the position you expected it to be?

Sven Ober

A Yes, within the accuracy of the GPS system, supported by very large buoys which were put on the measuring site for protection to make sure the fishery ships avoid them. Therefore, within that 1km to 2 km area we had an accuracy of 100 metres of where it was.

K G Robertson

Q Does anyone else have any ROV experiences?

John Dunn - Marine Laboratory, Aberdeen

A We have never actually used an ROV for recovering a mooring, but we have seen ROVs used to recover hydrographic equipment from an oil platform in about 4,500 metres of water. The problem with all of the ROVs is that in that type of water they have to use an ROV with what they call 'garage ROV' so that you have really quite a heavy wire holding a garage that weighs about 4 or 5 tons, lowered to within about 30 to 40 metres of the bottom and the actual ROV is flown out from that. You have a slight time-lapse in the pictures that you are seeing back because they are being sent back acoustically. It is relatively small and if you had a ship that was going out to recover a mooring it would be possible to accommodate it on a NERC type of vessel because it can just be lowered over the side in much the same way you would lower a package over. You would probably have to have someone who is technically qualified to operate it.

I would agree with our Dutch colleague, the pictures you get back really require an ROV pilot who can actually interpret. Watching how they recovered it, the ROV working there was sufficiently small that it did not have very sophisticated manipulators and what they did was put a line on to it - more or less like a quick-link line but when it came back up again it just trailed that line all the way back and then they used that line to actually target down a hook, which would hook on to the system and recover it in that way. According to them in 90% of the cases they go into, they recover it.

K G Robertson

Q I know that in the US there is something called a Lost Instrument Network and Scott has some literature on this but this can also be accessed through the Internet. Is there anything you can say about the structure of this Network and does it work?

Scott Worrilow

A This was something that was thought up and implemented by a gentleman from the USGS in Woods Hole. He has done quite a bit of coastal work and consequently he has lost quite a bit of instrument. He has his stories and I have my own about lost equipment - he found one of his buoys in some guy's front yard as a lawn decoration and he refused to give it up and he went back one night and secured its release!

He started this a couple of years and Dolly Dieter does know something about this. What I would suggest is that if anyone is interested - send me an E-mail and I can reply with his e-Mail address and he can supply you with a full statement of what is happening with this. It is something that we would really like to get going, not just for the work in the US, but worldwide because there are an awful lot of people who do go to sea and who will find things from time to time.

Another gentleman found a piece of my gear not too long ago and he actually tried to hold it for ransom! I had to get our State Department and our Judge Advocate General's office into it because he was trying to get a ransom to the tune of $8,000 - $10,000 and we haven't got that kind of money to pay somebody a reward. The fact that the equipment had been bought by the Navy, meant the Navy lawyers were willing to get into it and threatened international criminal case against the Captain for grand larceny because he was holding our equipment for salvage rights when salvage rights only pertain to a powered vessel. The fact is, it was not a powered vessel, he did not have salvage rights and it was clearly marked with our ownership but there is a lot to the story about how nasty this guy got and how nasty we got in turn. After a few months of going back and forth with this guy he tried to pull the wool over our eyes by keeping the acoustic release but he did not get a reward and about 2 weeks ago we did actually secure the return of the acoustic release, so we have now got everything back that he found on the surface.

Dick has mentioned and some questions were asked earlier, about not being in your office to receive telephone calls when something from ARGOS goes adrift. One thing that I have implemented at Woods Hole and it does ultimately save money, is that we monitor ARGOS directly through a modem. I have a person at Woods Hole who will log in three times a week to see if any of my transmitters are on the surface, so rather than relying on ARGOS notifying us that something is wrong, we do all our monitoring ourselves and don't rely upon anyone else. It does save money because you are not racking up ARGOS fees all the time and ARGOS wouldn't like me spreading the word too much but if you want to know where it is or if it is on the surface, monitor it yourself - its as easy as a telephone call and a modem hook up away.

K G Robertson

Q The Lost Instrument Network is operated by the US and maybe other nations have a similar thing but I also know that the ISOM Group some years ago suggested that a separate form of lost instrument network would be set up under the control of Europe. How has that progressed, did it get anywhere or were there objections to it, or is it that no nation can decide who should control it?

Mr C N van Bergen Henegouw - NIOZ, Netherlands

A The initiative to develop the form for Lost Equipment has more or less died slowly because it was felt that the loss of equipment and to salvage it was quite often co-operation between the party who lost it and a party who was able to recover it, so it was a bilateral thing. What we didn't make is a form to enhance that. It was felt that through the ISOM contacts of the ship operators, it was far more easy to contact the other ship operator who was capable of salvaging lost equipment, than to go to a separate or independent system.

K G Robertson

Q It sound as though the formation of a European Network is something that is not taking the same shape as the one in the US. Do people have this problem? Do people lose equipment and would they be pleased if there was information available to other ship operators, so that perhaps if they were passing the area, they might look and listen with the acoustics to see if they could hear these things? Or do people prefer to go and recover it themselves, or are they prepared to write off the loss?

Mr Ian Waddington - George Deacon Division for Ocean Prcs - SOC

A Most of us have lost equipment but I think the problem with losing equipment in the deep ocean is that where it comes up and where we work is very remote and it is doubtful at times whether ARGOS is of any significant value. It will identify that the buoys have come up and you have a problem. If you are going back to the area anyway you will find this when you get there. It will only help you in identifying the problem if you have to specifically mount an expedition to get there anyway. Usually the ARGOS runs out before that buoy comes ashore, especially when we are talking about central Pacific, Southern Ocean. Therefore, I think with regard to lost instruments the greatest value is really on the shelf edges. There should be a Network set up. We have discussed this to some extent and we were considering using Marinetech databases which surprisingly, very few people actually subscribe to, although this is a Marine Technology Database available in the UK and it is there if people are prepared to use it but it does need an initiative to get it going. People need to get together, we have lots of informal contacts in Norway and Holland and people are prepared to help but there is no formal network. Perhaps RVS would be a good place to start?

K G Robertson

Q The main problem is what do you do about it? It needs people to be there, it needs people on board to know what to do. It needs facilities to be able to help you and would you be prepared to pay for the ship diverting one day to recover your equipment? Is this where it begins to break down a little because of no real agreement?

Mr C N van Bergen Henegouw

A I don't know whether there is an agreement as such but the only way you can anticipate agreement is that you have made contact bilateral and so you have lost equipment and you probably know a contact through the International Ship Operators, where a ship with the capability of salvaging your equipment is in the neighbourhood and can be diverted. If there should be an extra cruise for a ship like that, I think everybody knows the cost of an expedition and it is probably not worth the effort anyway.

Mr K G Robertson

Q The other thing that is difficult to understand completely is if we have any legal obligations to recover equipment that we deliberately put into the ocean. I get stories that sometimes say "yes we should", that we have a moral obligation at least to clean up the ocean of the things we put in and sometimes I get a lot of information that says "no, there is no real obligation" but if we are in the waters of coastal states around the world, then things get more awkward and I do know we have had a lot of pressure from some states in Europe to recover these things that are floating in their water and are regarded as hazards to them. Where we stand legally I do not know. Of course it does cost a lot of money but the response to us is "you put it there, you get it out again". Does anyone have experience of this?

Scott Worrilow

A Ian Waddington, if your batteries are not long enough to operate the ARGOS for more than a couple of weeks, then you are almost defeating the purpose. The ARGOS that I have worked with and designed will operate for a minimum of 9 months, after it turns on, so it gives you time to find a ship of opportunity. The UNOLS Committee publishes where ships are on the Internet. Part of the problem I have found is that when you are looking for a ship you did not schedule to use, is that the information platform is not complete. You ask for what ships are in the North Atlantic at a given time and you don't come up with all the various names of the ships. The Ship Operators are not completing all the necessary information needed to keep this updated so that we know where the ships are. If you know that a ship is in the area, you put in a specific name of a ship and all it gives you is Northern Atlantic - that's a big place! You need more information and what kind of cruise it is on and a lot of the time it will only do it very generally but you really need to break it down. If you know a specific cruise schedule for a ship, send it over to the people in Delaware with the UNOLS Committee and I am sure they can incorporate it. Ken Robertson can give you more information on who to ask about ship use and if you are a ship operator, who to send the information to regarding where your ship is operating.

K G Robertson

After lunch on Wednesday we have a lady talking about the Oceanic database and she is from Delaware. If you are staying for this it will be most interesting because she is a source of a lot of information.

Mr Scott Worrilow

Obligations - As far as the equipment goes you can't guarantee 100% that you are going to get everything back for obvious reasons such as something breaking or fishing activity. I have done experiments in foreign countries and in order for us to get the clearance to do the work this has mandated that not only do we recover all the equipment but we also recover the anchors, so you have to recover the whole thing. When we worked on the shelf off the mouth of the Amazon River, the Brazilian Government mandated that we recover the anchors when we recovered equipment. So not only did we have to recover the equipment, in most cases we had to put a tether on the anchor so that we could remove the anchor once we had recovered everything else. Legally you can't be expected to recover everything all the time - there has got to be cases where something is left behind for some reason but be prepared, you might be required to move your anchors from time to time.

Mr K G Robertson

I believe if you deliberately leave something and you know where it is, the next time you ask for clearance from that State it may not be so straight forward.

Mr Scott Worrilow

In order to get these clearances you have to agree to write a report on what your findings were while working in their waters and this falls on the scientists, it does not fall on the technician - you have enough work to do! In order to meet the requirements of the clearance, the scientist has to write a final report to the country and let them know what was found and make all data available to them. Make sure when applying for clearances that the scientist takes a good look at the chart. We had an incident last year when we were working off the coast of Brazil. We had a Brazilian Naval observer with us and our clearance was such that we were allowed to work in coastal waters within a given window of time and then we were expected to go into International waters and then come back into Brazil to do more work; so for a period of 20 days we were supposed to be in International waters. There is a little group of islands about 300 miles off the coast of Brazil and Brazil claims this as their territory. One of our moorings was right on the verge of the limit and the Brazilian observer looked at the chart and said "I'm sorry but you don't have clearance to work in our waters, you can't recover that equipment until you have clearance". It took us 9 days to get clearance to recover this one piece of equipment.

Mr Richard Winterburn

Regarding Scott's comments on the duration of the ARGOS signal, the Smartcat Unit has an ARGOS only transmitter which is routinely configured with batteries for two years deployment.

Mr Ian Waddington

The point that I want to make is that all our transmitters will go for 300 to 400 days minimum. If you are operating in the South Atlantic it takes 40 days to get a ship there and at £9,000 per day that is not very cost effective to recover one buoy. By that time there probably has been a storm and you have lost all the gear underneath. I agree ARGOS is of great value but it is only of great value if you can get to the buoy. There is no point in tracking a £4,000 buoy in the middle of the South Atlantic with a £3,000 instrument.

Q. What measures do you take to ensure that you can recover the instruments without having to rely on ARGOS? I'm talking about putting in redundancy like double release gear or having possibilities to do some deep sea dredging yourselves when a mooring does not come up. Do you design a mooring so that when you hook on to it with the dredge, there is special weak-link so that you can break it off the anchor? Do you make provisions for this?

Scott Worrilow

A We have had such good luck with our releases over the years that we stopped using any dual releases years ago and we are well up in the high 90% recovery rate so we trust the one release. The preparation of the release is quite extensive so that we keep this good track record by keeping a good piece of equipment operating. We still lose moorings. It is common practice for us to go to sea for a recovery cruise with dragging gear in case we do not recover a mooring in the normal way. I have had quite good luck over the past few years when I have had to drag, getting most everything back and over the past couple of years with any dragging attempts I have got everything back, however that is pure luck. As far a weak links go, we don't have any weak links in there. It makes it more difficult when you don't have any sort of acoustic beacon that is operational on the mooring. Dragging for something blind is like a shot in the dark. If you have got something that is talking, then you have a good chance of getting it. Dragging is a little bit of science in itself but a lot of it is experience, a lot of it is luck but mostly its luck. I have just done this for Miami and got one out of two back complete and there was no acoustics on those whatsoever.

We did some dredging, not on a mooring but on the bottom line and we did this several times and got it up, so it was not a normal dredge. What we used was a weight, 500 metres of cable and a second weight and we know the position of the line and we put the first weight on the bottom, then we started to sail a circle and all we had to do was touch the bottom line and when we touched it, it came up and we did this in 2,700 metres.

When I do dragging I put a 500 lb. weight on the very end of the drag wire, I have upwards of 1,000 to 1,500 metres of wire and then I put another weight at that point, so that I know I have a good amount of ground tackle on the bottom. Making sure you have the ground tackle on the bottom is most important. We do strap big grappling hooks to that wire on the ground tackle. Then I put a pinger about 100 metres above that secondary weight, so that by paying out wire at the speed of the ship we can actually fly that pinger off the bottom, 50 to 60 metres, so that we know that the secondary depressor weight is close to or on the bottom and if you know that, then you know that the entire piece of ground tackle is on the bottom and the ground tackle is not going to come up and pass over anything. I have been on dragging operations where people have wanted to put in acoustic beacons on the bottom and have an acoustic net system on the bottom and have to transpond back and forth to 17 different transponders and releases - so the simpler you keep dragging the better chance you have of getting something back.

K G Robertson

Q I do know that in the UNOLS community of the US, they are keen on spreading experience from people like yourself and they are encouraging the production of instructional videos. I don't know how much has been done but you said yourself at the end of your talk that you hoped you had passed on some advice and information. What do you think about videos? The type of work that you do, that Ian Waddington (SOC) does, that Bill Miller (RVS) does? It seems to me that a video might be useful but experience is really the only thing that counts in the end?

Scott Worrilow

A A video is great but do you want to spend the money and make an expensive production or have conferences like these - there is the Buoy Workshop that was in May 1996, a Current Meter Workshop which takes place every 2 years sponsored by MTS and this Workshop. I think rather than having a video, having attendees come to these meetings because things change - this shot peening on the shackles is something which has come up over the past year. What is meant to be a tried and true technology really is changing and it changes annually and if somebody is looking at a video that is 5 years old, it could be outdated and it is putting good money after bad and I think it is best to have the personal interaction of people attending these meetings than it is to have a video when you can't ask anybody anything.

Q What do you think about exchange of technicians, so you can have a 3-month spell in another Institute. I know for Scientists it is normal, but for a marine technician it is not so usual. Is there not a possibility to make an arrangement whilst we are together to make a plan?

Scott Worrilow

A Earlier I mentioned reduced funding and I know the cruises I go on, I would welcome having people come over to help participate on the cruise and to learn about the equipment. The problem is if you have someone come over to work on the equipment, I don't have the time to train somebody. As far as going to sea, 'yes', I think people should be encouraged to go to sea because if you are paying somebody for a period of time when he is not that busy anyhow and you can afford to send him at your expense, then I think we should try to do that. I don't think you should try to get the people he is working for to foot the bill. If you are paying his salary anyhow, continue to pay his salary and possibly the people he is going to work with for a couple of months might be willing to pay for his air-fare and make some sort of arrangement for his accommodation. Ultimately it could cost both sides extra money and with funding as tight as it is now, it is tough.

Comment

You can gain a lot of experience by going to sea.

Scott Worrilow

A I think taking people to sea is a very good opportunity for people to learn a lot of different things and it should be encouraged. On most of my cruises there are a couple of training berths.

K G Robertson

It is a very good suggestion and I don't think anyone would disagree. Scott has said in this time of tight budgets and this is absolutely true. We have to watch who is going to pay for each item. No longer do we have the money to say it is a good idea, we will fund for 6 months, but perhaps I could look to ISOM and maybe Cok could mention this possibility because I believe at your meeting are the people who control the money and if they would be favourable to this suggestion, then I think it would be much easier. Scott is in a lucky position that some of the cruises he goes on there are additional berths. We find with the ships that we operate from Southampton that we have great difficulty in getting enough berths from the beginning and if we ask for an additional one for training, then very often the answer is "no, it is impossible" already we have two more - can we put an extra lifeboat on.

Mr C N van Bergen Henegouw

A Through ISOM there is an exchange programme for Marine Technicians and Naval Engineers. This is done on bilateral standards so if there is an idea of exchanging a marine technician between the UK and Japan (which has been done several times), it is done regularly but there are restraints like budgets and bunk space and there is really not much space for an extra technician.

Mr K G Robertson

Q How strongly do people feel about this and do you have the budget to support this exchange?

A. I feel that when we have a Workshop like this, we have to bring to your attention and the Scientist, how important it is, because as you said there are no berths so therefore there would be no technicians and no work would be done. We have to have new technicians and we need to bring it to your attention at this Workshop.

Mr K G Robertson

Q Let's make this a Resolution to push this forward - does everybody agree we should bring this to the firm attention of the Ship Operators (ISOM) who in the end control the ships, control the people who go on the ships, can make available the berths and maybe the money to allow this to happen?

Mr C N van Bergen Henegouw

A Can you do a report to the ISOM Meeting on Thursday 3 October 1996 and we will make it part of the discussion.

K G Robertson

I am due to give a brief report of this meeting to the ISOM Committee on Thursday and this will be one of the things I will stress.

Mr Edward Cooper - RVS

A I agree with the proposal that we exchange technicians and we put technicians on other people's ships. This time last year J Derksen sailed on the Charles Darwin and it was to actually help us out but it also helped him out because he looks after the computer system which originated with RVS and after talking to him this morning and he said he did not actually learn anything but it gave him confidence that he was doing things the right way. Also he did learn some 'tricks' with the system.

Make your representations to ISOM but you have actually got to make your representations to the scientists, because they are the people who are paying for the ship time and they are the people who filling up the ships with their scientific party. If we had enough technicians to put on the ships, we would struggle to get them on the ships because the way the budgeting is going for the scientists in the UK is that we used to deal with one organisation whether it be the Institution of Oceanographic Sciences or a particular University Department. However, their money is now so segregated that in order to undertake operations they are involving huge numbers of groups and each one of those groups wants to be represented on the ship and we are getting squeezed as technical staff off the ships and for example - "Discovery" has a berthing for 28 people - my view is that 20 of those people ought to be technical support staff and 8 scientists but it is totally reversed. We sail with 24 scientists and 4 technical staff and maybe 2 or 3 can be added to the technical compliment - up to about 7. If Ken or Cok would like to expand the resolution to ISOM but it has got to go a lot further than that, in that we increase the technical ability on the ships and leave the scientists on land. Let them plan their projects but have their projects conducted by technical staff.

K G Robertson

I am sure most people here will agree with this!

Comment

I do not agree that we have to change it from 20 technicians with 8 scientists but I think we have to say to our scientists you need more technicians. You also have to give them a way to learn new techniques which is most important. You have to be careful to have a good balance.

K G Robertson

One of the other problems, as Harry Bryden said this morning, it is very rare now that one scientist and his people occupy a cruise on the ship, it is more common that many groups of scientists will go with different funding sources and they will combine to make a whole cruise and then it is more difficult to confine the number of scientists and work the balance out right.

Mr E Cooper

This may be a point particular to the UK. In the UK we are confined on working hours for technical support staff at sea and we run into problems because the organisation puts rules on us which are backed up by the European Community, on the number of hours that an individual can work during a 24-hour period and must have so many hours rest and this makes the technical operations very difficult and to support the marine technician, it aggravates them. I have been involved in this sort of science for 17 years and I come from an era where the technician did anything he could to make the job work for the scientist, but now there is another party (the people with the money!) and they've come in and said "thou shalt not work more than 13 hours in 24" and this is why you need more technical staff on the ship in order to make the job run smoothly and I would like to know if similar rules operate in the US or in Europe?

K G Robertson

Q Does anyone else have these restrictions?

Scott Worrilow

A Yes, it is more relaxed. I think people would like these kind of restrictions in the US but who is out on the ships who can watch over this. If you have something that is half-way in the water do you have to break people off and replace them with somebody else? If I am on a ship and I'm not supposed to be working and there is something going on, then I'm working anyhow! There are times when you have to pull out all the stops. On the Darwin cruise that I spoke about this morning, I worked an average of 21 hours a day for 12 days straight. You have to know when to take a break but you have to get the work done. Regulations and stipulations set on you from people who have never been to sea is ridiculous.

K G Robertson

I will make representation to ISOM later in the week and I think COK will also to the Ship Operators but how do we get to the scientists who use the ships and they are important people. I don't see a central way of doing that. Do we have to tackle this in our own Institutes separately? We have agreed on the exchange of technicians and training of more technicians and perhaps altering the balance a little to get more technical people on some of these cruises, but it is true that we have to tackle this with our scientists on a local basis?

Mr R Lowry - BODC (British Oceanographic Data Centre)

“Operations in support of Oceanographic Field Programmes”
(Large field programmes which involve 30 to 40 cruises.)

I am a Geologist by basic training and researched in high temperature and experimental geo-chemistry, but for the last 15 years I have been working in oceanographic data management, initially as a scientific programmer and over the last 8 years I have been running a team that provides support to these large scale oceanographic programmes, including running a centralised data processing facility. BODC is the British Oceanographic Data Centre and we are located at the Proudman Oceanographic Laboratory which is in Birkenhead, just South of Liverpool.

We are a team of about 20 people, of which 6 of us are engaged in this type of work. We have a national oceanographic data base, we have another team who looks after that and we also handle electronic publication products like the UKD map, the GEBCO digital atlas and we run a real-time data acquisition system of tide gauges - the UK A class network.

In the major scientific programmes starting with the UK, we essentially act as an interface between the shipboard data collection and the scientist using the data. The tradition in the UK with RVS is that RVS' responsibility for handling the data stops when the ship docks. When the data comes off the ship they have an initial calibration. It is not the final calibration and some parameters aren't calibrated for example, the fluorometers, you can't calibrate them until someone has analysed the chlorophyll samples and they usually come off the ship as filters in dry ice, so the job cannot be totally finished on board. We take over from there and provide an interface to the scientific community.

Requirement of a Large Project

What the scientists want to do is synthesise and interpret data from a large number of cruises or in the case of the last project we were involved with, which was the E.U. OMEX project, from a large number of platforms. OMEX involved 47 cruises, off 11 ships, of 9 different nations. Bringing that together into a synthesised data set has a whole host of problems. If you are synthesising a data set, the vital thing is that those data are internally consistent, both in their content, what parameters are measured, the format, how those parameters are presented to the scientist and quality.

Consistent Content

The common parameter set is vital. There is no point in having every ship going and measuring its own independent set of parameters with no overlap. If you are synthesising data a common parameter set is vital and including null channels aids synthesis. Simple example - ship 1 on its CTDs is measuring temperature and salinity, ship 2 has a fluorometer on its CTD. If from ship 1 you include a fluorometer channel that is fully null, it is a lot easier to take those two data sets and piece them end to end. It is a very simple point, but it makes the job of bringing together the data sets and merging them, far easier. The other problem in content is parameter names - schizophrenic parameter names should be avoided. If you have a set of characters that is a parameter name it should mean one thing and one thing only.

When I was thinking about this, an example jumped from my ‘black book’ which is a parameter called DWIRR which has landed during the last 12 months containing a raw light meter voltage, a calibrated light meter which I think in micro watts per square centimetre with energy per unit area and then on another cruise it turned up and it had a nephelometer voltage in it. When this arrived to us it was confusing. I think something that can be done very easy which would make our job far easier and improve quality by elimination of errors, is if there was a formalised naming. If you had a simple database - “these characters mean that channel from that instrument”. If someone wants something different - “I want this bit of processing done on that channel”, then call it something different - it is quite a simple thing to do.

Synthesis from multi-formats is a tiresome chore and I can tell you that from experience. The OMEX data arrived to us and it was in 22 different formats for CTD data. We are fortunate that we have specific software tools designed for reformatting data and we have a data definition language which we can use to describe the format, we write a very small amount of code and we can reformat. It is usually about 2 hours work to handle a format. We are fortunate in that situation. Most of the scientific community does not have this luxury and if they are delivered data in 22 different formats they would make 6 months work sorting it out. However, if anything can be done to ensure that formats are consistent, life would be much better and simple things such as if you have the same channels in the same order each time they come off the ship, it would make our life very very much easier.

The cruise I was on last week a set of SBE25 data, 24 casts. The first 11 casts had the independent variable as pressure in decibels and for some unknown reason casts 12 to 24 were as depth in metres. This comes about because when the technician is processing the data, he is faced with a set of menus and he makes the choice that is felt appropriate at the time or he has a scientist standing over his shoulder on the ship at the time saying “wouldn’t it be better if we did this?”. They don’t think at all about the consequences of what happens when those data get on to land. If I hadn’t built an automatic check into the reformatting software to interpret the header, this would have gone unnoticed and we would have had a set of data in metres processed and handled as if they were decibels.

With consistent quality you need consistency and the best way to get this is that there are many wrong answers but only one right answer, so if you have high quality data automatically those data will be internally consistent. This is the WOCE philosophy and it seems to have worked well, particularly with the physical parameters. WOCE temperatures, salinity, oxygen - the WOCE data I have seen have been very high quality indeed.

One way you can improve quality and the internal consistency is by internal and external intercalibration. Internal intercalibration is if you have got 3 sensors on the ship measuring the same thing, then you perform a intercalibration exercise. One of our standard practices is always to intercalibrate a thermosalinograph against a CTD. External intercalibration is the intercomparison between platforms. You bring 2 ships together, put a CTD down and collect a set of samples and you get both ships to measure them and compare the results. It is a good idea also to get the analysts to swap the samples and analyse each others samples, otherwise people will say “the intercalibration shows there was a difference between the two water masses despite the fact you can’t actually throw a brick between the two ships”.

Unification - we want to get rid of inconsistency and one way we can do this is to make data available in a unified product specification. We will make your CTD cast look like this! We output this in a common format, so all the OMEX data currently available from BODC are in exactly the same format. We undertake quality control, so we try to unify quality control procedures and see what ships from different nations have done and find the highest common denominator, so we can find the highest quality data set and if there are procedures that are regarded as not being to the same quality, we try and apply the higher quality procedures to bring everything to a common standard.
Intercalibration - we do intercalibration between instruments on the same ship and we also try out intercalibration exercises between the ships.

Added value through data documentation. If you pick up a set of 10 year old data and you just pick up a set of numbers you have salinities but are they 1 decimal place accurate, or 0.1 decimal place accurate, or 0.01 decimal place accurate - this is not known? Unless there is a set of documentation going with those data that describes what instrumentation was used, what procedures were used, what calibration protocols were applied and also reporting if anything that was known to have gone wrong, any problems. If that is in the document with the data, then those data will be of equal value in 20 years time as they are today and with the current trend in science to have a look to see if there are long term trends with respect to things like global warming; being able to use historical data reliably is becoming increasingly important. Therefore, we ensure that everything is documented. An example of a unified product that we make available, the CTD’s our standard product, is that we take the data from the downcast, calibrate it and tidy it up and bin it to 2 decibels. We have a parameter set defined, the CTD information from us will always contain these parameters, even if there is no data for that parameter, we will just tag a null channel on.

The quality standards for all data points are guaranteed. We look at things point by point, we go through and we try not just to have the average approximately right but if there is some kind of artifact where the instrument at a certain depth has gone haywire, we will take those data out of the data set. We also undertake intercalibrations between different platforms and between the different instruments and we act upon them. There are so many intercalibration exercises where it has gone on and people have got their results, they have looked at them and said “that’s a bit different to that!” and that is as far as it has gone. No-one has actually said “this is the definitive data set”, there has been no great effort in identifying which are the problem data sets and therefore no correction has come out of these intercalibration exercises. If intercalibration is going to be effective it has to be looked at, followed through and the good definitive data sets identified.

The advantages of the unified product are since this is made easy bringing these CTDs together, if someone wants to produce a four-dimensional field, for support of modelling. You simply roll in stuff that is all in the same format, bring it in, throw it in to your melting pot and you have the modellers ideal data set. The other advantage of the unified product is that it gives the non-specialist scientists something they can handle. For example, with physical data, temperature salinity, I think the vast majority in terms of numbers of users are biologists and chemists who are looking for those data in support. If you can feed them the CTD data in a form they can feed inside EXCEL and produce their plots, look at it and compare it with their own data sets, which they are working within EXCEL, they are happy. So this standardised product makes life very easy for a large number of our users. There is a disadvantage of course, there will always be a scientist who wants something different, no matter what you produce, it will never be right for everybody. There is also the problem that as time goes on the required specification might change. An example of this is that another channel might be added to the CTD and then all of a sudden people want historical data looking the same as the same channel set there are getting for their current CTD data. There is an answer to this and that is to generate the unified product dynamically. By this I mean within our data base we store the data fairly much in its raw form. We don't actually apply the calibrations. The calibrations we determine are held elsewhere in the data base as algorithm codes and coefficients. Then we run the retrieval programme which pulls out the data, it dynamically applies the calibrations and then bins the data. So if someone wants something slightly different, we have just got to modify the software slightly to handle their requirements. It works from the same base data set. Also if your specification for the unified product changes, you simply modify your software. If someone wants data from the past in that same form you just put in the programme again.

Handling the problems of common format - This is quite simple from our point of view. You have data from a range of different formats, you load them into a common database, once you retrieve from that common database, everything is in the same format.

Quality Control - We have got a graphical interactive editor called SerPlo. I have played with quite a lot of graphical interactive editors over a time. SerPlo is the best I have used and this is a very powerful tool. It is very fast and very smooth and it means that we are able, without putting undue amounts of manpower into it, to graphically inspect every data point that passes through us. Therefore, all the surface measurements are scanned, all the CTDs are scanned and everything is looked at. It is looked at by qualified scientific personnel. In the team we have got people from a range of scientific disciplines but by the time they are trained through they are experienced oceanographers. It is also context sensitive; one thing SerPlo does is, as it presenting the data to you, it also presents a cruise track, so you can tell if this is data from the open sea or data from inside the estuary. This makes decisions on, "is this a spike or is this real?" far sounder. Also the quality control method we use is to tag the data points with non-destructive flags. People can have a look at the decisions we have come to and see what was suspect data or what was it good data and those decisions are open to inspection by any scientist using the data and they can make their own different decisions as they so wish.

Calibration - We want the best but we want it realistically. We handle huge amounts of data to look at and to calibrate, with a team of 5 people. We have a great deal of experience in dealing with scientific data and we are working with the scientific community and there is a bulk of experience out there and what we do is we go out and talk to people. It is quite easy sitting at scientific meetings to pick who are the best in any calibration field. We go out and talk to them, talk in detail about what their procedures are and we bring their procedures into our own. We are always looking to improve calibration procedures but we only do major changes between projects so when we come to the end of a project, that is the time to do the review. In this way the data from a project are consistent.

CTD Salinity Example - (*Fig. 1*) Data are processed following best available advice, then we need to look at salinity bottle determinations against the CTD profiles. We have tried various automatic techniques but because we have got a very fast graphical editor, you can sit there with two screens on the desk, one is an EXCEL spread sheet with the bottle data in it and the other is a graphical workstation showing up the profile. You can look at the profiles and identify where bottles were taken on gradients. You can identify where bottles were taken at times with noisy instrument performance and in that way you get the rubbish out of your calibration and you are only left with good bottle samples to intercalibrate. In doing that you get a fair idea if you have got any duff bottle salinities in the data set. They show up quite clearly from that process. If you have a very stable water column, three comparable points, one point is a bad comparison, it is a fairly good chance that one bad comparison is a bad bottle value.

You then have to ask the question, which is more accurate, the CTD or the salinometer? This very much depends on what kind of CTD instrument people are using and what kind of salinometer people are using but you have to ask this question and find this out. If you think that the salinometer is more accurate then you work out the offset between the CTD and the salinometer data and you apply it. You use the salinometers to change CTD data. If you don't believe the salinometer is more accurate, then what you do is use the bottle data as a monitoring technique to make sure nothing drastic has happened to the CTD calibration and that it inter-compares but in that case you don't use the bottle data to change the instrumental data.

Intercalibration between Sensors. We calibrate temperature and salinity, we calibrate thermosalinographs using CTDs as secondary standards.

Intercalibration between platforms - On OMEX, one of the intercalibration exercises I did was to draw up the TS diagrams from each ship when they put a CTD down in the deep water off the Golden Spur, a nice stable water mass. You know what the TS curve should look like and I was quite amazed when I plotted out these TS curves and they all overlayed. I have great faith in the OMEX data set. If you get something in an intercalibration exercise, decide which are your right data and act upon it. There is no point in paying lip-service to intercalibration; it has to be used to improve the quality of the overall data set.

BODC at Sea - We try and get a BODC representative on as many cruises as possible and there is, of course, the inevitable berth restriction but I fight my corner quite hard on this. Why is it, what do we do at sea? The first thing is data management, preparing an accurate catalogue of what data were collected. This is a data management thing, it has no quality implications but if you are going to build a data base of the data that were collected on a cruise, if you don't know that someone collected a particular data set on that cruise and you have got no chance of getting it into the data base. It is hard enough getting it in when you know it is collected and quite often on inter-disciplinary cruises you get 10 PhD students who all write everything down in their own note books. Getting an overall picture of what went on scientifically is very difficult.

Putting a Data Manager on there whose primary responsibility is producing this catalogue, makes the databases that you build from that far more complete and useful to scientific communities in the future.

The other thing we do is to go round and make notes of how measurements are being taken and what protocols are in action. Are people using GFF filters? Are they using GFCs? It is amazing how many times you will find a situation where someone has been using one type of filter and all of a sudden they are on a cruise and they discover they have brought the wrong box, so they start using a different filter type. That is never recorded, but has important implications in terms of what those data mean, particularly if you are looking at biological parameters. The difference in using a 0.4 and 0.2 filter has an awful lot of difference in what phytoplankton community you are looking at.

Data Quality Enhancement - On the UK ships the primary role of making sure the ship's systems are operating correctly is the responsibility of the RVS technicians on board and one thing a lot of scientists don't seem to appreciate is that these guys have to sleep, so if we have got someone on board it is another body and another pair of eyes and it means more hours in the day and the instrumentation is being watched. If something goes wrong then hopefully that it is noticed that much quicker and is repaired that much quicker.

Increasing the number of calibration samples. What we try and do is to cajole people or even roll our sleeves up and get involved. BODC personnel have filtered huge numbers of chlorophyll samples to increase the density of the calibrations. I have spent happy hours sitting in front of a salinometer to get more salinities done. It comes down to the fact that you have limited resources on a ship to get things done and if we put some resource in there and help get more out of it, then so much the better.

Collation of Information - This is another of the roles - basically what we need to know about the instrumentation, what sensor was in place, where, etc., making sure that it is all brought together and acted upon.

Supporting the Science - Berths are in quite short supply and we always make it quite clear to scientific parties that we will help out in any way we can. I try and choose the person who goes on the cruise to match the type of cruise. We have biological oceanographers, various scientific skills within the group and we try and match so we can help as much as possible.

Training within BODC - Understanding and working on marine data - unless you go out to sea and see what it is like and see what actually happens, unless you really understand the hard work and see the hard work, if you try working that data up afterwards, you are wasting your time. You really have got to go out there and see what is happening. I have been going to sea now for 12 years and I still learn something new every time I go out. On the last cruise I did, I learnt that what happens to a thermosalinograph if you have a piece of equipment that is not earthed somewhere else on the ship. It causes the sea surface temperature to drop by **c** °.

Data Management. We put data into a project database so each project we support has its own Oracle ID and the data are assembled in there. The system I was describing before in terms of unified products, this allows us to evolve quality. The raw data are stored there, the calibration algorithms and co-efficients are developed in that data base through time. When you get the data out it reports the current state of the calibration on that data set. Therefore, the scientist can pull it off two days after the cruise and he will get a fairly raw data set but it will say it is a raw data set. He pulls it up 6 months later he will get a polished product, the format has fields that report this fact. We allow project participants to log on to our system and run various application programmes, or they can use native SQL to pull up the data. This is an area I am looking to develop and I would like to go to some kind of client server systems where the scientist sits in front of a access form which comes over the wide area network and pulls data down but this is a dream at the moment. At the end of the project the scientist can turn to the paymaster and say "look here is the data set and here is something tangible from this project".

Project Data Base - It is a relational database under Oracle. It is a totally separate database with separate IDs and in that way we can handle the problems of security, who exchanges data with whom. They all have separate passwords. What the relational database does is allows all these complex multi-disciplinary measurements to be handled in one relational framework so if you want to compare a benthic pore water profile with the water column profile overlying it, the relationships are there in the data base and it allows you to get to the bits of information you need.

Quality Evolution - Essentially our databasing system allows the data to change. We don't have to recalibrates or reprocess it, it is all to do with the retrieval programme which processes the data dynamically according to stored information.

Tales from Roy's Black Book

There are a lot of entries in here and my intention in describing the adventures or misadventures is not to critisise, it is to point out things that can be done cheaply and easily that would stop these problems arising again. Nine nations have worked in OMEX so I would say to my colleagues in RVS that when I am telling these tales that do not necessarily relate to UK ships.

The biggest headache we have is communication breakdown. It is not being told things that we need to know. One of the major reasons we started putting people to sea was because these problems were arising and this was an attempt to improve this. Even that does not work perfectly and I have had events happen where I have been in my bunk at sea and I haven't been told; I have found out about it by accident. There seems to be a reticence to make information known. It is something I have tried to understand but haven't really understood but if the information flow can be improved, things regarding oceanographic data management would work a lot smoother.

Here is a classic tail:

On a recent cruise a scientist brought along his own nephelometer which was bolted on to the CTD and for convenience, the light meter which wasn't used on deep casts, they just plugged the nephelometer essentially into the light meter socket. When we look at the data, if you have a cast where there is no light meter attached, the form of that profile looks almost identical to a nephelometer profile. So we got this data set, we looked at it and said "Oh - no light meter fitted" and we dumped the data channel. We sent the data off to the scientist who owned the nephelometer and got an irate e-mail back almost by return saying "where's the nephelometer data gone". The fact was nobody told us a nephelometer had been fitted. We had no reason to suspect that a nephelometer had been fitted and no reason to expect the nephelometer data suddenly to turn up in the light channel.

Another case:

I was trying to calibrate a fluorometer against extracted chlorophyll and it looked like somebody had been firing a shotgun at the graph. Data was scattered everywhere. Having a look carefully at the plot, I thought I could see two straight lines in it and I investigated a bit further and separated out the two data sets and I found that one data set corresponded to the first half of the cruise, the other data set corresponded to the second half of the cruise. Coincidence?? - we start ringing round and are informed we changed the fluorometer half way through the cruise. Again we were not told.

Why does communication breakdown happen? One reason is people don't expect that we need to know - in fact if you are handling data coming off a cruise, you can't be given too much information. I would far rather be swamped with information and filter out what I need, than lose something.

The other problem I think is that other people are entrusted to tell us and I suspect that the worse offenders in this category are Principal Scientists. They are given a report at the end of the cruise which the technicians on board naively assume will come to us in the form of a cruise report. The North Sea project cruises were in 1988/89 and I am still waiting for 6 cruise reports from those cruises to be written, so don't assume that someone else is going to tell us - tell us directly.

Another thing is we waste time - we are messing around and things aren't going right, we make a telephone call and then we get the information. There is also the problem that we can do things in ignorance that degrade the data quality. If every time we got a data set there was a short report of information and that report was electronically attached to the data, then I think a lot of these problems could very easily be overcome.

After not knowing things, time is my biggest headache. The problems fall into two categories:

1. Lack of synchronisation between times.
2. Time zones.

No synchronisation - one of the commonest things we are required to do by scientists is to merge data sets into a common time base. The time stamps for these data sets come from a range of sources, clocks on various PCs, scientists watches, wrist watches are used for timing when chemical samples are taken. If the time stamps aren't synchronised then you start comparing the wrong values, so if you are doing a calibration you completely mess things up when comparing the instrumental reading with a sample that was apparently taken 10 minutes earlier. That really does mess up your calibration. Also if you are trying to correct things logged by separate instruments. An ADCP records the velocity of the ship relative to the water, navigation records the velocity of the ship relative to the seaflow. (I am talking about deep water here, not bottom tracking). You have to combine those two vectors to get what you want which is the current. If you have a 10 minute offset or, as I have found on one occasion, an hour and a half offset between the two time channels, the quality of your final data set is going to be seriously compromised.

Time Zones - There was a infamous cruise I had which shall remain nameless, that was running local time. During the cruise local time switched from GMT +2 to GMT +1. Ship time did the same and so did scientific time, but various people changed their watches at different times and sort of came together over a 12-hour period. Bringing this lot together on a common time basis was an absolute nightmare.

Therefore, the universal objective should be a universal source for all time stamps. If this is not possible then daily attention should be paid to synchronisation. Never change your scientific time zone during the cruise and if possible, standardise on GMT, it makes global set synthesis far easier if you are working to one common time zone. I am talking to an audience of technicians here and I am not sure if the scientists are aware of this problem. Some of them are and some of them are horribly ignorant of these little details.

Finally from the black book - Good Intentions!

We had auto-analysers that were being continuously logged on one of the cruises and there was a helpful chap who developed a system to convert the voltage stream from the instrument to concentrations in micromoles.

This was then fed through various bits of software and produced a nice coloured contour plot showing the nutrient distribution over the cruise. I was on the cruise when this happened and this plot was laid out on the table and a group of scientists were looking at it saying "Isn't this fantastic, isn't this amazing, isn't this is beautiful!" Then when we had a close look at a certain river estuarary we found that as you went further up the estuary into fresher water, the nutrient concentrations were going down, whereas everyone would really expect them to go up. The cause of this problem was that the analyst had changed the gain on the colour imitator, because you are going into high concentrations you flip the instrument onto another range. The processing system did not pick this up.

So the morals of this tale are when you are flying by the seat of your pants check, check and check again. The other moral, which is a point I keep making to scientific audiences, is that the credibility of a data presentation is directly proportional to the number of colours it contains.

Therefore, in a concluding summary, what can we do to improve data quality?

1. Intercalibrate at every opportunity and act on the results.

2. Take as many calibration samples as analytical resources permit. In taking bottle salinities it does more than calibrate your CTD. If there is a rosette fault then the salinities can quite often pick up that fault and your whole bottle sample data set can be salvaged on the basis of a salinity data set.

3. Strive to improve the quality of accompanying information.

4. Pay a lot of attention to time-stamp synchronisation and if you try something new what I call "flying by the seat of your pants" at sea, then carefully check all the consequences, check the data from every possible angle. If somebody had looked at the time series of these nutrient data the problem would have jumped out.

My final concluding remarks bearing in mind what I have said about colours and contour plots, a presentation made to you in glorious black and white but I hope it is still believable.

K G Robertson

Q At the beginning you said "you haven't yet seen any bad data in the WOCE data set" and again you commented on the quality of OMEX data. If I have read you right - what conclusions do you make of that? Have people all been to hear your talk and taken note of what you are saying or is there something else?

Mr R Lowry

A I am not the only one preaching the gospel by any means! With WOCE I am talking about two parameters in particular - temperature and salinity. Our experiences do not extend to other parameters and it is again generally the UK WOCE that I have been exposed to. You have people in SOC like Peter Saunders, who has retired now, but whose influence is still there. People have been preaching data quality in the WOCE community and that has had an effect.

In OMEX we have been paying attention to data quality but I know I am by no means the only one who takes great interest and great pride in the quality of the data that is produced both on the UK ships and ships of other nations. I have been around looking at procedures and it is quite encouraging to see that quality is taken seriously. I know there are many people preaching this gospel for high quality data. This is physical oceanography, basic temperature, salinity, those data channels.

When you start moving away into chemical and biological data sets, then you are on different ground and if I might answer one of the comments before about JGOFS protocols, these have been presented and put forward for adoption but one of the problems I have seen from my perspective is that are too many people around who think they know better. So OK the protocol says "I do that" - "but no I can do this, which makes it even better". It is surprisingly difficult to enforce a discipline on to scientists to follow somebody else's protocol. You have only got to look at the NABE (North Atlantic Bloom Experiment) data set which is supposedly to a common set of protocols to see. There are practical problems that come up - I encountered the nutrient auto-analyser chemistry that is proposed for JGOFS works fine with certain makes of auto-analyser but it doesn't work with another brand of auto-analyser. So if you happen to be a laboratory that's got £100,000 invested in this piece of kit, you can't go out and junk that and go and buy another piece of kit - it is just not practical. So there are practical problems as well that stop people following the protocol to the letter and once you deviate from the letter, then you start getting differences as shown with that Copper data set. It doesn't take a huge difference in protocol to make quite a dramatic shift in the number that you get. You may not be measuring quite the same thing!

K G Robertson - SOC

Q The role that you take and your staff take when you go to sea as Data Managers, can I ask you if this is something you have decided to do because nobody else does it well enough in your opinion? Is it something you would prefer the scientist and the technicians working together as a team to be much more aware of and leave you to your real job?

Mr R Lowry - BODC

A It comes down to consistency, some Principal Scientists believe that bringing information together is part of their job. Some Principal Scientists could not care less about it. If you want something to happen, by far the most effective way is to go out there and do it yourself. You can shout and scream and persuade and ask people, go out and tell them what to do and because it is not their main line, even with the best intentions, it always comes last in the priorities. Then some other emergency or problem crops up and it does not get done. By actually having someone there whose primary responsibility it is, then it happens and it happens consistently. I feel if it becomes a secondary job that someone else is doing with the best will in the world, there are times when it just does not happen and once your records start to become incomplete, you just as well not bother.

Dolly Dieter - NSF

Q What protocol or what procedures do you have to ensure that your scientists will actually turn the data in? In the US it is a major problem getting the scientist to turn the data in to NODC.

Mr R Lowry

A It is the international problem of data management. In the US the major technique that is used is the funding weapon. I work quite closely with Chris Hammond in the JGOFS Data Centre and I am well aware of the procedure in the States. The way I like to do it if at all possible, I want the scientists to want to give me the data. So by providing a service that is helpful to them and having some useful currency, one way that works quite well is we take the CTD data straight off the ship, work it up and hand it out to the scientist. If the scientist has a sample data set they want to compare to a CTD, it is quite easy to negotiate a simple exchange.

I think that bringing out project deliverables and establishing an identity with the scientific project, BODC staff turn up at all the scientific meetings and we try to become part of the science team and in that way people feel they are exchanging data with one of their own and not throwing it into some black hole where it will disappear never to be seen again or even worse given to their worse competitor outside the project. I have worked and really strived over the last 8 years to develop a relationship of trust with the scientific community.

With the data projects we are handling at the moment it is paying dividends. I would say 90% of the data I get in is handed in voluntarily and I have to use the big stick 10% of the time and the mention of contractual obligations, etc. The big stick has a sting in the tail - people will throw data at you and throw absolute rubbish in your direction which is of no use to man nor beast! They will just clear the messiest files they can find on their hard disc and put it on a floppy and say "here you are, I have satisfied my obligation". That is no good, you want people to work with you to a common aim.

Mr Sven Ober - NIOZ (Chairman of the Management Group of CTDs)

“Developments in Ocean Thermometry”

A well known problem with CTD data sets is the long time needed to process raw data up to WOCE/JGOFS quality. In times of budget cuts it is hard to find money to pay this processing labour. For scientists it is attractive to have the data available as soon as possible. An analysis showed that the calibration of the CTD sensors is one of the most time-consuming processing-steps. Increasing the quality of the calibrations and sensors will result in an substantial acceleration of the data-processing.

During a visit to Sea-Bird Electronics Inc., Bellevue, USA the CTD calibration problems were discussed thoroughly. One of the most interesting subjects was a CTD intercalibration experiment carried out by R. M. Hendry, BIO, Canada. A surprising result of this experiment was the discovery of a dependency of the temperature signal on winch-speed. This effect was measured with a EG&G MK-V CTD-system. Figure 1 shows the difference between the static measured temperature of deep isothermal water and the measured temperature during yo-yoing vs. instrument speed. It became clear that turbulent dissipation in the direct vicinity of the temperature sensor caused a temperature rise of a few mK depending on the water speed relative to the sensor.

Mainly due to ship movements (heave, drift, etc) this water speed varies in time causing extra noise in the temperature-signal. The Sea-Bird SBE-9plus is an isobaric pumped CTD-system so the water speed relative to the temperature sensor is constant. The temperature effect is therefore an offset of a few mK. compared to WOCE- and JGOFS standards this is significant. Sea-Bird modified the nozzle of the temperature sensor tubing assembly (Figure 2). This modification reduced the water speed and consequently the temperature offset. The temperature offset should be far below significance level now. In order to check this out a Temperature Calibration Experiment was planned and carried out as an additional program during the WOCE cruise in the Bay of Biscay in summer 1995 and 1996.

Just before the start of the 1995 cruise Sea-Bird finished the development of a thermistor based reference thermometer. The (claimed) features and specs of this thermometer are impressive and listed below:

- Accuracy (of the calibration) : 0.5 mK
- Drift : < 1 mK / year
- Resolution 0.025 mK
- Time-response 0.5 sec
- “Listens” to bottle-confirmations
- Memory for 156 measurements
- Fits in water triple point cells and Gallium cells

This thermometer, the SBE-35, was (beta)-tested during the cruises as well.

Objectives of the Temperature Calibration Experiment

1) Check the SBE-3 temperature sensor for warming due to turbulent dissipation.

2) Beta-testing of the SBE-35 reference-thermometer.

3) Increase the quality and processing speed of the WOCE CTD data-set.

Calibrations

1) A SBE-9plus CTD system with an extra set of T and C sensors was shipped to Sea-Bird for a full system check and calibrations of all the sensors.

2) 10 SIS electronic reversing thermometers were calibrated using the NIOZ temperature calibration facility at (nominal) 0, 1.6, 2.4, 2.6, 2.8, 3.3, 5, 10, 15 and 19 degr. C. The absolute accuracy of the facility is about 1 mE C.

3) 4 SIS electronic reversing pressure meters were calibrated by SIS, Kiel, Germany.

4) A computer controlled Guildline Autosal 8400B was installed in a MOSES laboratory container. The climate control of this container was fine tuned in order to obtain a stable ambient temperature.

5) The SBE-35 was calibrated against a NPL water triple point cell at sea and in the lab. In cooperation with the Dutch National Laboratory of Standards, Department of Temperature and Heat, calibrations against a their water triple point cell(s) and a Gallium melt point were carried out.

6) The NPL water triple point cell was recertified in the framework of this experiment.

7) The Guildline Autosal 8400B was calibrated by Guidline a few month before the cruise.

The Experiments

1) The bottles at the positions 2, 4, 6 and 8 of the CTD frame were equipped with sets of 2 reversing thermometers and 1 reversing pressure meter. From every bottle at an uneven position (1, 3, 5, etc) + the surface-bottle a salinity sample was drawn. The salinity samples were analysed within 24 hours. These calibrations of temperature, pressure and salinity form the backbone of the CTD data set and the Temperature Calibration Experiment. After the cruise all SIS measurements and salinometers results were checked individually and in case of any doubt (e.g. gradients, heavy sea state, human failures, etc) the measurement was rejected.

2) As primary thermometer was used an SBE-3 thermometer in the usual pumped way. The new nozzle was mounted so there shouldn't be any significant warming. During 16 deep casts (> 3000 m) a second SBE-3 thermometer was mounted immediately beside the primary temperature sensor, however without being connected to the tubing system. From this unpumped secondary thermometer the nozzle was removed allowing the water flow freely around the thermistor needle. During the rosette stops the water speed relative to the secondary sensor was low and determined by the ship movements (heave, drift, etc.). In case of significant warming by turbulent dissipation (viscous heating) Tctd,pri - Tctd,sec should be positive during water sampling. The data of the two thermometers (Tctd,pri , Tctd,sec) during a rosette stops were obtained by averaging 1 sec of data (after standard high accuracy postprocessing) using the bottle confirmation bit in the data stream.

3) The SBE-35 reference thermometer was mounted as close as possible to the two SBE-3 thermometers. A measurement was done during each rosette stop.

5) The SBE-35 was calibrated against a water triple point cell at sea.

6) In co-operation with the Dutch National Laboratory of Standards the SBE-35 was calibrated against a water triple point cell (4 times) and against a Gallium meltcell (2 times). In combination with the triple point calibration at sea and the factory calibrations it is possible to obtain an impression of its stability, the transfer accuracy, reliable resolution and noise level.

Summary of the results (1995)

SBE-35 against WTP-cells and Ga-cells:

- All the calibrations were within the accuracy of the cells.
- Drift is less then 0.2 mK/year
- Claimed accuracy and resolution are realistic

Comparison of the SBE-35 with ERTM (p>3000 dbar)

- ERTM - SBE-35 = -0.6 mK (SD=1.2 mK)

Comparison of T(pri) with SBE-35 (p>3000 dbar)
SBE-35 - T(pri) = -2.1 mK (SD=0.4mK) (Figure 3)

Comparison of T(pri) with ERTM (p>3000 dbar)

- ERTM - T(pri) = - 3.7 mK (SD=1.7)

Comparison of T(pri) with T(sec)

- T(pri) - T(sec) IS POSITIVE AND PRESSURE-DEPENDENT (Figure 4)

Comparison of SAL(ctd) with SAL(sampler)

- SAL(sampler) - SAL(ctd) IS POSITIVE AND EVEN MORE PRESSURE-DEPENDENT (Figure 5)

Conclusions (1995)

1) New nozzle does **not** solve the viscous heating problem (no WOCE specs).

2) The observed temperature difference is pressure - and/or temperature dependent.

3) Something is wrong with the conductivity sensor (no WOCE specs).

4) The claims concerning the SBE-35 are realistic.

Response of Sea-Bird

- **Nozzle**

  New nozzle does not solve the viscous heating totally. Residual effect ca. 1 mK.

  Action:
  Modelling the effect and development of correction software for Seasoft.

- **Pressure effect**

  30 % of the sensors do have this effect. Cause is not exactly clear.

  Action:
  The calibration procedure will be expanded with a pressure test.

- **Conductivity-sensor**

  Probably two causes:
  1) The use of artificial seawater for calibrations.
  2) Residual pressure effect.

Action:
Change to “real” seawater for calibrations and the calibration procedure will be expanded with a pressure test.

Summary of the results (1996)

All the calibration results were comparable with the results obtained in 1995 with 2 exceptions:

Comparison of SBE-35 with T(pri) ($p > 3000$ dbar)

- SBE-35 - T(pri) = **0.1 mK** (SD = 0.6 mK, N=70) (Figure 6)

Comparison of SAL(ctd) with SAL(sampler)

- SAL(sampler) - SAL(ctd) is positive and pressure dependent, although less then in 1995 (Figure 7)

Final conclusions

1) The pressure and viscous heating problems with the SBE-3 thermometer are solved.

2) The problems with the C-sensor are not solved.

3) The SBE-35 sensor meets its specs and is probably the best oceanographic thermometer available.

4) The SBE-3 and SBE-35 provide the means to meet the WOCE accuracy for temperature easily.

Mr Nordeen Larson - Sea-Bird Electronics, Inc

"Using a primary temperature standard at sea: A case study on WOCE P-15S"

I was admonished yesterday about the word primary temperature standard so I will correct this. The SBE-35 thermometer which Sven has just talked about and the statement that we are calling this thermometer in conjunction with the Gallium and the Water Triple Point Cells, the primary standard, is incorrect, because the primary standard is the fixed point temperature cells in conjunction with a valid thermometer. This is not valid on ITS-90, only a standards grade Platinum thermometer is valid. Therefore, I should just take my pen and correct the talk right now.

What is the motivation behind this?

These are some of the WOCE lines in the South Pacific just off the coast of South America (*Fig.1*) and if you look at what is going on, the temperature comparisons in the deep ocean where the WOCE hydrographic lines cross each other, can be compared in the bottom 500/1,000 metres and some of the comparisons are not very great, so apparently the temperature measurements are still quite difficult. These are different kinds of CTDs from different Institutions. A graph like this can cause people to start pointing fingers at each other which is not very productive.

One of the interesting things here and the reason we are involved - this line here P18 (*Fig.1*) was done with a Sea-Bird CTD and all rest of these are non Sea-Bird CTDs. One of the interesting things here is that in comparison in the places where the WOCE hydrographic lines cross, Sea-Bird is systematically colder than anyone else. This caused us to worry about what could be going on because in our view about the only thing that could go wrong with our temperature measurements is that they might register warmer than correct, from a pressure effect, perhaps just plain miscalibration might make it colder than correct.

In the deep ocean, the errors we are aware of would make the temperatures warmer than correct. So to attack this problem and try to figure out what to make of this data, we began to develop this SBE-35 thermometer and the principle behind it was we wanted to minimise the amount of error in getting the calibration on to the thermometer and getting it into the deep ocean to try to measure and certify what the CTD is doing. So the thermometer was developed with a very long stem so that it could be placed down into the triple point of water cell and also down into the Gallium melt cell, to pick up a calibration directly from those defining fixed point temperatures. Therefore, this talk is really about what happened on the cruise. I went out on a cruise on P15 South between New Zealand and Antarctica and tried the new thermometer out. Here is a discussion of what happened during the cruise.

First of all we calibrated the thermometer and got its basic calibration curve by comparing it to a standards grade Platinum thermometer and this was done in one of our baths at Sea-Bird. Here is the SBE-35 being loaded into the bath (*Fig.2*). There is the calibration bath (*Fig.3*) which is about waist height (1 metre deep). The standards grade Platinum thermometer is in there (*Fig.4*) in a vibration isolation mount, the SBE-35 is hidden behind.

Once the basic shape of the calibration curve for the thermometer is established, then just as in the philosophy of a standards grade Platinum thermometer, where the calibration curve is known, there is a second step to the calibration, which is to take the curve and re-level it, so it exactly goes through the Water triple point and the Gallium melt point temperatures.

The Gallium melt cell, if you are unfamiliar with it, is a cell that is full of Gallium. In the liquid state it looks like Mercury and in a cold state it looks like a cold solder joint, just a grey lump of metal. The cell is frozen so the metal is solid, the cell is a few centimetres in diameter. There is a re-entrant well that goes down through the centre of the solid ingot. When the cell is warmed up, the ingot is promoted to melt and now just like an icecube in water you have a Gallium cube in Gallium and you have a stable temperature.

With the right procedures, putting the thermometer in the cell, you can then monitor the temperature of this melt with time and this is what happens (*Fig.5*). It is now is 1 milli-degree full scale, each one of these lines is 1 hour, so the melt proceeds for approximately 12 to 15 hours and for theoretical reasons, we grab the temperature at the top end of the melt plateau as likely to be most correct and we take this point and we offset and slope correct the calibration curve to come and lie right through that point. For the thermometer in this cell we would have expected that our SBE-35 read 29.764325EC (*Fig.5*). David Ayres will explain later why this is different from the standard number.

Here is our Metrology lab (*Fig.6*); this is where we maintain our standards grade Platinum thermometer. Those familiar with the equipment will recognise the Autosal for salinity work and this is a maintenance bath for water triple point cells and here is a Gallium cell with the SBE-35 in it a registering a melt.

If you look at this a little more closely (*Fig.7*) we have a melt going and we are running now a comparison between the standards grade Platinum thermometer and the SBE-35 Water triple point, that is releveling the other end of the curve at zero. That is how the thermometer is calibrated. Then to develop this thermometer tool we have to not only be able to use it in the Laboratory but out in the ocean. Getting it out in the ocean is not a problem - this thing is easy to ship but in our test we wanted to take a Gallium cell to sea to check the performance of the SBE-35 at sea, during the time we are using it to check the CTD. We choose to bring the Gallium to sea rather than the Water triple point because Water triple points are more fragile and Gallium looks like a good candidate to survive a lot of abuse. We intentionally took it into the Antarctic Polar current so we could just beat the hell out of it and see what happened!

Getting it down there is a problem because Gallium is a class 8 shipping hazard. If it gets really warm, like fire temperatures, it eats Aluminium so pilots don't want it on their aeroplanes but you can overcome this. We had a special case built and certified for shipping Gallium cells (*Fig.8*). These are now available by the company who builds these for about $200. What costs you money is the stamp which certifies it to IATA (International Air Transport Association) that this case qualifies as an approved container for shipping Gallium around.

We load the Gallium cell into this box along with just standard food grade cold packs and in this case, in a room which is 25EC. This will hold the cell below zero for 48 hours. This allowed us at Christmas time to take this to New Zealand and get it on to the ship and still the temperature inside the cell when I opened it about 4 or 5 days later was still below 10EC. It was clearly solid and if the packing case had tipped over, there would have been little or no damage to the cell.

We set up shop on the ship (*Fig.9*) - the equipment doesn't take much room - the Gallium melt cell, a PC, monitor and a few tools for producing the melt and getting things going. The scale of this whole project for certifying temperature is very small.

We start by running melts on the ship to certify the long stem thermometer and here is a series of 5 melts (*Fig.10*) and this looks an awful like the quality of melts in the laboratory. They rise about a tenth of a milli-degree in 12 hours and it is very easy to pick off the top point. The surprise to us is that once we reached Tasmania and were getting on the ship, the calibration of the thermometer had apparently dropped 0.3 milli-degrees.

We brought 2 thermometers down, one to sit in the laboratory and monitor what was going on with the Gallium melt cell and the other one to be used in the ocean to take the pressure and temperature cycle. When we overlaid some melt checks with the thermometer being used in the ocean, we find the same thing, so both of these SBE-35 thermometers dropped in calibration during shipment. Something is going on, both of them drop the same amount. Nonetheless, think of what we are talking about, the drop in the calibration level was 0.3 milli-degrees.

Here is a series of calibration checks (*Fig.11*), the entire cruise worth, the laboratory thermometers going in to the Gallium cell while we are doing intensive CTD work and the long stem thermometer coming off the CTD package and getting recalibrated. The total envelope of variance on these melt checks is 0.6 milli degrees. Clearly the tool is working fairly well and if I can just rearrange this and take the melt temperatures as a function of time, this is what we see (*Fig.12*) - calibrated leaving Seattle we had adjusted the thermometers so they agreed with this expected temperature. Arriving in Tasmania we find them to be 0.3 milli-K low and the thermometer used in the ocean changed its calibration a bit. The thermometer used in the laboratory looks a little variable but didn't change as much. Again I want to emphasise that this scale right here (*Fig.12*) is 1 milli-degree and it is very tempting to look at this and say this thermometer is drifting up and then levelling off. What we are talking about are signals that are sub milli-degree.

The summary (*Fig.13*) of the performance is that the long stem thermometer in December 1995 just before the cruise registered a stability of 0.05 milli-K in our triple points of Water. We didn't have any triple points of Water during the cruise. After the cruise it is registering a stability of 0.1 milli-K. We brought the Gallium melt cell out to sea to check the performance. In the laboratory at Sea-Bird before the cruise, there was a +/- 0.1 and you get a shift down 0.4 milli K. At the end of the cruise the ocean going one is a little above the calibration set in Seattle and then in the several months following the cruise it stayed within 0.2 of the expected calibration range. The laboratory thermometer we brought out on the ship, just to monitor what was going on with the cell itself, shows the same sort of pattern.

As a comparison this is what our real primary standards are doing. This is with a standards grade Platinum thermometer. In all of 1995 we get this kind of performance (*Fig.14*). In 1996 this performance (*Fig.15*) and in the Gallium melt cells the total envelope performance is well within those ranges, so this ocean going thermometer is not a lot worse than the Platinum thermometer used in the laboratory and yet the ocean-going thermometer has survived shipping in a cargo container and the vibration levels at sea.

As Sven Ober said this is not a profiling thermometer. It grabs a measurement when it hears there is a water bottle being commanded to be closed, so it stops and integrates for a while and grabs the temperature measurement at the bottle stop. If we plot the comparison between the CTD temperature sensor and the SBE-35, what we find is that the data are in reasonable range from zero to 6000 metres and on a scale where this is 1 milli degree. What we find is that the CTD temperature sensor is reading fairly close to the standard thermometer at the surface, it is about 0.4 and there is definite pressure effect. The comparisons get a little bit better in deep water, it is more isothermal up where the gradients are, where we are getting about +/- 1 milli-K. It takes a composite of 8 or 9 stations to get a pretty good trend going on.

We had anticipated this sort of problem that there may be a temperature difference between the location of the measuring element in the long stem thermometer versus the CTD package. Primarily because the CTD is producing heat in the water column - there is a lot of electrical energy being dissipated down there and a good example of this is in Ross Henry's report where one of his graphs demonstrates that down in the isothermal water region, the CTD will shed up to as much as 2 milli-K filaments of heated water off the CTD package and off pumps and other things that are running.

That is a possible reason for the variance and one of the ways to get rid of this in the measurement scheme is to pick up the temperature sensor and turn it around, put it in the mount and place it tip to tip with the standards thermometer and then we connect the pump to the port, so we are pulling water and running it across the CTD temperature sensor and immediately across the reference temperature sensor. So whatever the temperature down there, whether it is polluted with thermal plumes off the CTD or not, both thermometers should read an integrated temperature over the same packages of water.

The scheme works quite a bit better and now we have a ¼ milli-degree variation up to high in the water column. I think it is fairly obvious that over a large range of the water column it is easy to verify what is going on between the standard thermometer and the CTD thermometers and what do we see, the top temperatures are pretty good and there is definite pressure effect. The tool looks like it is working very well and is working at a sub milli-degree to verify what is going on in the CTD.

What kind of checks can go on?

In the ocean if you are running 2 CTD thermometers together, you can look at the difference between the two. Looking back at a graph that I have just shown, our reference thermometer is telling us that the temperature sensor on the CTD has a pressure effect in it and this is looking something like 1.6milli-degrees positive in 6,000 decibars. A check was made of that sensor in our pressure bomb and indeed what we are finding is when we pressurise the sensor to its full rating of 10,000 p.s.i., or about 7,000 decibars, we do get an organised difference from our reference at Sea-Bird, which is something like 2.1 milli-K in 9,000 and this would be about 1.4 milli-K in 6,000. At sea we are getting 1.6 which is a very good agreement but what it means is that this tool can be used at sea in the environment right away and be detecting errors at milli-K and sub milli-K level, even looking at pressure effects.

So - what do we have as a summary of checks on the CTD temperature performance?

The accuracy at the surface looks like it is within a milli-K. The surface is an important area although the mixed layer temperature variance makes this comparison difficult. This is an important area because the pressure up here is equivalent to that in the Calibration Lab. In the Calibration Lab. you are in just a few metres depth in a bath. This takes out any possible pressure effect.

Pre- and post-cruise calibrations of the CTD sensors set a limit on the drift. The temperature sensor comparisons out at sea give us some confidence that no one sensor is drifting off and in fact, on this cruise 3 separate temperature sensors were used. The pressure effect on these sensors is determined at about 1½ milli-K at 6,000 decibars and we saw it in three different methods of measurement, that this tip to tip method just nails it down in a single profile and it is fast and easy and produces very clean data. The viscous heating is about 0.5 to 0.7 milli-K and this is also evident in some of the data.

Conclusion - How well is the new tool working?
At sea the stability seemed to be better than +/- ½ milli-K, in fact the total spread of variation at the calibrations of the SBE-35 thermometer were within 0.6 milli-K, so +/- ½ milli-K at sea.

The accuracy
If you look at the cells themselves, the triple point of Water and Gallium melt cells, these certifications that come out of the US National Standards Laboratory, or Isothermal, the company who make them, the certifications on triple point of Water are +/- 1 milli-K, certifications and on the Gallium melt point, are 2 milli-K. At first glance it would be unreasonable to claim better than the certifications coming out of the National Standards Office. If you look into those Standards Labs and see what they are doing and what you can do yourself with careful work, it is very clear that sets of triple point cells will all measure to far better than 0.2 milli-K and that sending your triple point cell off to the National Standards Laboratory does certify that you are clearly within this range on that particular cell. The Gallium melt point cells are easily stable at 0.5 milli-K.

So, while in the formality of ITS-90, the temperature definition, we can't really get under these certifications for the cells; clearly in the Metrology Lab, it is easy to do better work. Part of the reason for this certification is it is an accumulation of errors in bringing the six cell temperatures out across several intermediate calibration steps, until you finally get on to a production sensor. With the SBE-35 we are going into the cell and picking up the temperature directly. We are circumventing some of the errors that are built in to this number. We are probably better than 1 milli-K, maybe 0.5 milli-K.

We are still trying to work with groups who have the formality to tell us what is going on but it look like we are better than milli-K, so in conclusion to all of this, can we go back and solve this problem and the answer is **Yes!** We now have a tool and a method for verification of what is going on in temperature and we can begin to solve this puzzle. The solution to the puzzle is either the temperature instruments are wrong or the calibration applied to them is wrong but it is tough to believe there are incompetently managed Calibration Laboratories. The other possibility is this is real oceanography and we may have to face up to that.

Mr Paul Ridout - Ocean Scientific

Q The problems you encountered with the conductivity side of the Sea-Bird, was the calibration for conductivity done with or without the pump in the Calibration Laboratory?

Sven Ober

A With the pump.

Paul Ridout

Q In our Laboratory where we calibrate Sea-Bird occasionally, that is the ones that don't go back to Canada, we find we can't get the standard sensors near enough with the pump in place.

Sven Ober

A I mentioned the observed pressure effect in the conductivity cells and because of that, Sea-Bird built a pressure bomb and intercalibrated to conductivity cells are bumping water around under pressure, so the water was moving.

Mr Paul Ridout - Ocean Scientific International

"Counting the Cost of Calibration"

The company is based in Petersfield UK and was formed in 1989, primarily to take over the operation of the Standard Seawater Service from the Institute of Oceanographic Sciences where I was employed as a marine chemist for 12 years prior to that. Part of my job outside of my research work then was to carry out the day to day operation of the Standard Seawater Service. The company was formed to take that over and since that time we have expanded our operation around our specialism. So we have developed seawater standards for other purposes, the latest, which I will mention in more detail later today, a seawater standard for dissolved nutrients. We are also involved in development of other seawater standards including carbon dioxide standards jointly with Scripps.

A natural progression from that was the development of a CTD Calibration Laboratory and we operate a commercial calibration facility which is contracted for the next 3 years to carry out the remainder of the UK WOCE CT calibrations. We don't manufacture any instrumentation but we do act as European Service, Sales and Repairs Centre for one or two North American manufacturers and we also help to market sampling equipment and some analytical equipment produced by one or two of the Research Centres in the UK - Southampton Oceanography Centre being the obvious one.

The subject of my presentation is "Counting the Cost of Calibration" and the obvious impression from that is, what are the financial costs but in fact when I started to research this it was much more involved and two-thirds of my talk will be nothing to do with finances in the terms of hard cash but it will be more to do with counting the cost of not calibrating or not calibrating properly. So the scientific cost rather than financial one. However, there are always financial pressures in what we do and that will have some bearing on the last third of my talk.

Most of the applications we are talking about include calibrating marine instruments but there is a huge range of applications in terms of the types of instruments used and what the instruments are used for. For instance, we get involved in sea surface measurements, atmospheric measurements and so on. The trend for the future is likely to be data buoys. There is certainly a large number being deployed at the moment and we expect a larger number in the future.

Many meteorological instruments, sea surface temperatures, salinities, currents, waves - all these things involve some form of instrumentation for which, if the data is to be comparable throughout multi-national programmes, calibration is an essential component. Instrument packages that we are all familiar with in various shapes and sizes, optical instruments for measuring chlorophylls, fluorescence, transmissometers, turbidimeters and so on, again all present some problems in making the data comparable and meaningful.

Current Meters are very widely used and there was a lot of talk in Moorings Programme yesterday about the use of current meters. This reminded me of an incident that happened to me on Saturday when I received a telephone call at lunch time from a local BBC Radio Station because apparently an American couple on a cruise 13 years ago off the coast of the US, dropped a bottle off the side of the boat with a message in it and put a cork in the top. The bottle was found about 2 or 3 days ago on the Scottish coast by a child out walking and contacted this couple and as a result this has made the news and they needed an Oceanographer or expert to explain what the fate of this bottle might have been in the last 13 years. The WOCE programme cost in the last 7 years about $1B but I managed to sew the whole problem up in 5 minutes on the local Radio. There is a cost element saving there I am sure!

Towed bodies are used widely now and are likely to be used more. The data gathering capacity of a towed body is generally greater than using fixed line dips for CTDs but again the sensors that are applied to those instruments need to be treated in a special way in terms of their calibration, their sensitivity and the mode in which they are used. Also you will find now that with some of the more recent profiling towed bodies, they are being used much more on the inshore environment, coastal environment and estuary studies and even in small lakes, because the small lightweight bodies are capable of being used behind a boat almost as small as an inflatable. That usually brings in a lot more parameters, measurements inshore and coastal pollution studies, pH. measurements, all have sensors which require calibration.

In seafloor studies too there are a lot of chemical measurements that are made in the sea and calibration is also critical to those. The chemical sniffers that are used for detecting hydrothermal vents all require calibration of one form or another to meet their goal. The use of the data then knocks on into all the applications like ocean bathymetry, sea surface salinities, studies of the polar icecaps and so on. They all present their own specific problems. For example, if you are doing CTD or temperature measurements in and around the polar icecaps exclusively, we get involved in calibrating probes for that application and we do the calibration in a very tightly defined temperature range, instead of just doing it over a wide range we can calibrate in a very small low temperature range for this sort application, thereby improving the data quality. Any sonar measurement again, requires temperature salinity or some other form of sound velocity measurement to calibrate the sonar devices that are used.

Finally WOCE (World Ocean Circulation Experiment) has been mentioned quite a lot in the last 2 days and for us also this a very important feature and much of the work involved in climate study relies on good comparability of data.

What is important? First of all you must make an assessment of what your data quality requirements are because there is no point in buying instrumentation or calibrating instrumentation to WOCE specifications if you are doing a pollution survey on the coast or in an estuary. You have to gauge what you require first of all by your data quality. We were discussing this morning that the JGOFS requirements are different from the WOCE requirements, therefore the protocols are different and the requirements for the instrumentation are different. You should know what you want in the first place.

The important thing is; measurements you may make from a small boat (and lots of measurements are made from small boats with a bucket or whatever) are going to be generally less stringent in terms of calibration requirements than you are going to need if you are out in the deep ocean.

The situation varies a bit in the coastal environment, it depends on the application, but whatever it is the costs of the calibration have to be taken into account. You planned your scientific programme, booked your ship time or whatever method you are going to use to get out and get the samples. You have bought the equipment which is relatively expensive and everybody seems to forget about calibration at that stage. During the cruise planning, there is very often an awful lot of things to think about, but calibration does not often get costed and so it is left to the last minute; usually out of the consumable budget or someone else’s consumable budget and so calibration can become a last minute panic in terms of the cost.

Data Quality Requirements

International Programmes
WOCE, GOOS, TOGA, JGOFS, LOICZ, CLIVAR are all international programmes and WOCE involves scientists from over 30 countries. They have to be able to work to a common protocol **-** they have to have a common standard. It would be a complete waste of resources if the data could not be compared.

Intercalibrations
Intercalibrations were mentioned this morning **-** QUASIMEME, which is the European one that involves trace metals and nutrients, for example. ICES have organised a number of intercalibrations and we have been involved ourselves in a calibration on CO_2 measurements. Intercalibrations can be demoralizing **-** as an analyst it can be daunting also. It is very easy to lose your confidence and not return any results at all. This is not very valuable for intercalibrations and the slide that we saw this morning from Dr Kramer, showing the variability in Copper, just gave an indication and I think in some ways it can also be reassuring to realise that there is variability. As an analyst you can perhaps feel a little bit safer in company but if you are involved in the quality data side, it can be worrying.

QUASIMEME for instance, took a very interesting stance with regard to data quality for nutrients. They were very keen to improve the quality of nutrient data around the 50 or so laboratories involved and so they set limits that they would accept from the laboratories in the area of +/**-** 50%. I was at a meeting in Miami a few years ago where David Wells from QUASIMEME made that statement and there were gasps of horror from the JGOFS and WOCE community on the American side, as to whether those data would be in the slightest bit useful with such a huge confidence limit. In fact, the philosophy behind it was quite an interesting one because the idea was not to lose the confidence of the laboratories early on, by giving them big limits that they could fall inside and then gradually encourage them by improving their methodology and new standards and so on, to actually improve the quality. This is a different point of view.

Monitoring Programmes
These are going on all the time - many of our customers are now what are called the Environment Agencies and were the River Authorities. They are continuously monitoring our coast line, looking at pollutants, bathing water quality, health hazards. As to the quality of their data, a lot of their measurements are relative measurements, they don't have quite the demands that we have to find the true value. Having said that, there is a trend now with these organisations to push their limits of precision and accuracy further, in that whereas before they were using relatively crude hand-held salinity meters and so on, they are beginning now to come more into the CTD market and are getting more interested in proper laboratory salinometers for instance, as they are being driven to higher quality data.

Survey
Environmental impact studies, bathymetry, construction - they are a nightmare for us. Running a commercial calibration laboratory, survey companies always ring you up about 24-hours before they need the instrument back and they haven't even sent it to you at that point. Everything is done last minute and that's usually to do with the funding coming through very late, so if ever we are working over night or on a weekend, it's because a survey company has just come in with another CTD.

WOCE Accuracy Requirements

I am going to be talking mainly about WOCE CTD calibration because that is what we do a lot of, but we do get involved in other things. (*Fig.1*)

Temperature - 0.002 deg.C (ITS-90).

Salinity you will notice I have put no units for this, so before anyone corrects me, there are no units for salinity but that is a message that has poorly got across since 1978. It will probably change again before the idea creeps in. You will still see the old units of parts per 1,000 and the strange little symbols that are like %, with an extra 0 on the bottom. You will see also this unit which is called a PSU (Practical Salinity Unit). There is no such thing, it does not exist but it has been invented by scientists who used parts of 1,000 for many many years and could not cope with not having units any more. The reason there are no units is that when the salinity definition was changed in 1978, it actually became the Practical Salinity Scale and it is a scale now based on actual measurements, not a concentration. The only analogy I can draw, if it helps you at all, is pH. We are all used to samples having a pH of 7 or 9 and we don't expect any units on the end of that. That's what the Practical Salinity Scale should be like.

WOCE have set quite high standards and as was mentioned this morning, they researched their protocol before they produced it. We were involved in reviewing the salinity protocol. The way WOCE worked, to their credit, is that they sought out as many of the top experts that they could find for each of the parameters because the difficulty, of course, with any protocol as we did discuss this morning, is it is not always accepted. There are some areas, an example of that is still the measurement of pH in seawater, where there are 2 or maybe even 3 different sections of science who will not agree on the method. Somebody eventually has to stand up and say "for this programme we are going to use this method".

Salinity was not so bad because it was a well established definition, there was a good standard and as it happens, there was only one machine that would really come up to the specification which made life a lot easier. However, the WOCE Standard has been adopted by a whole range of organisations now who are not involved in WOCE and never will be but use it as a desirable goal for their data quality and also a number of manufacturers of instruments will produce a WOCE CTD for instance, which is giving it an impression of its performance. We operate the WOCE CTD Calibration Lab and so we are seeing quite a lot of instruments, different ones that were involved in that programme.

Achieving Data Quality

This not always as easy as stating your data quality requirements. WOCE made those requirements for their programme but they based it on what they thought was the best data attainable for instrumentations.

Previously, 0.002 in salinity was considered to be the best operable value that you could reach. They were the best under good conditions with trained analysts and calibration will come into this. How well can you calibrate? Generally speaking in a calibration lab you should be calibrating with standards which are an order of magnitude better in their accuracy and an order of magnitude lower in their detection, than the instruments you are calibrating. It is not actually possible in the case of temperature now but it was decided that they could get near enough and in fact, the achievement for calibration in terms of data quality from these parameters is that they get increasingly difficult. Conductivity, temperature and pressure are fairly well established and although they are based on chemical properties, they are essentially physical measurements which make them much easier to calibrate. Phosphate, silicate, nitrate, and nitrite which are classic dissolved nutrients, are chemical measurements, and up until recently have been quite difficult to calibrate, especially with different methods of measurement. Again the improvements are coming there.

Sound Velocity is OK - you can calculate sound velocity from temperature and salinity but there are a number of sing-around sound velocity meters around now whose specification is better than the calculation specification so there is some difficulty there. When you get into currents and waves, it is even more difficult because you can't recreate the conditions. You have no standard and it is very often a relative measurement and that is the only way that can be described.

The method for calibrating fluorescence in the laboratory is very crude and has no bearing on the real environmental measurements. If you calibrate a fluorescence chlorophyll sensor, you use chlorophyll A dissolved in a suitable solvent. All you do is test the linearity of the instrument and its performance over a set concentration range. When you go out in the ocean and measure fluorescence, you measure the fluorescence of chlorophyll A in a living cell which is why samples are always taken at sea and brought back to the laboratory and the measurements done afterwards to get a more 'real' picture. Standards are important in this aspect of the work too.

Calibration Requirements

So what do you look for in a calibration, or in a calibration laboratory, or in a calibration facility whether it be commercial, or in-house or a manufacturer? Accuracy has to be the most important feature. Accuracy meaning that the value you get from your instrument is near to the true value and how you estimate the true value is something else, because there are very few measurements that are made in science that are true values!

We all read in text books about the estimation of conductivity. The theory of it is relatively easy to understand - two plates a certain distance apart, etc. and certain dimensions but when you actually try and build something like that, absolute measurements are very difficult to make. IOS where we were originally, spent nearly 25 years building an absolute conductivity device - there were only two built in the ocean world - one was here and one was in Paris and we got one measurement out of it which we still use. It was a very important measurement and it is still used in the Practical Salinity Scale 1978, as being the absolute conductivity value which the scale is forced to fit at salinity 35.

Nearly all the measurements we make are relative measurements so the true values are some sort of primary standard which I will mention later, in fact that is where the traceability comes. We have to trace back to a primary standard in temperature, the triple point cells. Perhaps an analogy there would be the unit of measurement. We all use rulers and tape measures for measuring and all those are traceable back through various improving accuracies of measurement until I think a Standards Laboratory in Paris has a standard metre, based on the wave-length of light. Accuracy, calibration and traceability are essential.

Other added advantages in the calibration laboratory, or certainly desirable features, you really want to minimise the down time since you don't want the instrument to be in the calibration laboratory for three months of the year and then used for two months of the year. You don't want it to be a very slow process, so generally you want to minimise the downtime of the instrument, because you bought that instrument to collect data, not for being calibrated the whole time. We find fault detection crops up a lot in calibration. Instruments are sent to us particularly by survey companies who already suspect there is a problem with it and they let the calibration bring out that problem because you are working under test conditions. You are looking not just at the values but at the behaviour of the instrument, its linearity, the quality of the noise, or lack of noise, data stream, etc. Fault detection and correction, of course, is desirable within the calibration facility.

Operational knowledge of the Instrument
There are many temperature calibration laboratories, there are many pressure calibration laboratories, however, there are many not many salinity/conductivity ones but I feel that there is a great value in having operational knowledge of the instrument, knowing what the instrument is used for and how it is used. Then you have a much better understanding of its behaviour when you are trying to recreate that in the laboratory.

Accreditation was mentioned this morning and a quality system is actually important because it is your record keeping. Record keeping is an important part of calibration as a history for a machine is very important and the history for a probe. Therefore, a quality system should ensure that type of system is kept properly.

What methods are used in Calibration?

None? - I know places that have no calibration at all or they use the phrase, "we calibrate our CTD once every five years whether it needs it or not!" There are all sorts of reasons but some people don't formally calibrate their instruments.

In house checks - this is like a low key version of calibration **-** you don't need so much equipment and you can dip it in a bath and put another thermometer along side and check if the values are about the same. It has value in that it can increase your confidence, or decrease it if it is way out but it can generally increase your confidence if the machine is still working properly. It can also complement a calibration. Maybe you don't need to calibrate all the time but an in-house check every now and again will ensure that it hasn't been damaged or is not drifting. So it is useful in fault finding.

In-situ calibrations are used a lot and are essential but they are not a replacement for laboratory calibrations, they usually are in addition. For instance, conductivity is a classic example, not many people, certainly at the WOCE level, would rely on a laboratory calibration for conductivity. We have done many, many, conductivity calibrations and it tests the performance of the machine and coefficients that are put into the software and you get a very good result but conductivity cells are prone to all sorts of problems. They dry out, or depending what sort of cell it is, they get bubbles on them, they get fouling on them, all these things affect their performance far more than they would a temperature or pressure sensor. Therefore, most people would expect to do them with the more traditional bottle samples.

Other aspects of in-situ are dissolved components and so on, that generally require some sort of in-situ checks. The trouble with in-situ calibrations is that they can be expensive. You need a lot of equipment, a lot of people take it to sea. Autoanalysers are taken to sea and very often salinities for CTD calibrations are done on board ship and this is quite an expensive was to do it.

One of the advantages, particularly with salinity measurement, is the use of a common standard whether you are doing in-situ calibrations or whether you are doing in-house checks or full calibration in a laboratory. Is there a common standard or a common primary that you work with? With salinity particularly, it is I suppose a great success story because back in 1900, a forward thinking Danish oceanographer called Martin Knudsen came up with this idea that if we produce one source of a seawater standard then that could be used for everybody and so the data could become comparable. Salinity is one of the most measured parameters in the ocean anyway and over the last century now, there have been literally millions of salinity data points and a lot of those data are still comparable because a common standard was used and also with the Practical Salinity Scale being a common acceptedly definition and method generally, the comparability of salinity data has been particularly good.

In-situ calibrations are familiar to most people using rosettes and water bottles but they all present their own sorts of problems. This is not the time or place to go into details about getting the best salinity measurements but again Dr Kramer mentioned this morning about the importance of sampling. We run a two day salinity course on a regular basis both here and at customer sites abroad and we spend some time with sampling because as we discussed this morning, there is no point in measuring salinity to one part in 35,000, if the bottle has already been contaminated in the way the samples have been taken. The aspects of sampling are very important.

When the salinity bottle is used to take the samples from the Go-Flo bottle, all sorts of things can happen with an untrained sampling scientist or technician. A simple things like filling the bottle too full for instance. We get a lot of contract analysis and bottles are sent to us. When they arrive they are full to the brim and the top has been screwed on and the first thing you notice as you undo the top is you get a crunching noise which is the salt crystals that have dried. That is bad enough in itself but the fact that they filled it to the top means that you can't mix the bottle because there is no air space. If you can't mix the bottle, you can't measure the salinity because it stratifies in the bottle. If you pour a little bit off the top what you have got left is not the original salinity because you have poured fresher water from the top. Little things like that make a big difference.

When making the measurements on the machine itself we have certificates for calibration and we have certificates for insurance and health, what about certificates for analysts and the quality of their work, because even with the best standards and the best equipment you still need trained personnel. They need to be able to operate the machines properly. There has been a huge change in instrumentation which is why there are so many more technicians involved now. It is far more technical than it was before and you need far more knowledge of a wide range of equipment and its operation. The old days of oceanography would be that the science driven project would be driven by the scientist and very often he would make his own equipment and he would take it to sea and work up the data himself. So he was involved in knowing what the overall aim of the project was right from the start but it is not like that now, as we all know. It's lots of computers and people sitting at desks with modems, satellite dishes and many more things. A lot of high-tech equipment and the data gathering capacity is much higher and the reliance on the technicians is extremely high. Training and experience is important in terms of use of various equipment involved.

This brings me back to standards because one of the things that we can find an advantage in with a standard is that sometimes a standard can help to take some of those variables out. On our training courses we run salinometers, different models all in the same room, with analysts some of whom have never seen a salinometer in their life before and others who has been doing it for 20 years and when we have put the data sets up at the end of the day, they are usually within 0.002 of each other. A lot of that is due to the use of a common standard of course.

Here are a few examples we have encountered in our laboratory which might cause a problem if you took some of these options:

No Calibration - This is a drift characteristic (*Fig.2*) for a CTD which was widely used in WOCE but not a WOCE specification CTD and this was the quoted drift characteristics. The bottom line is the WOCE requirement of 0.002 in temperature and conductivity/salinity. If you did not calibrate this instrument and sat it in the laboratory under the best conditions this is what the manufacture says would happen to that probe. So you would be far out in temperature and far out in conductivity at the end of the year - about 12 milli-degrees and 0.036 respectively.

In House Checks - This (*Fig.3*) is another CTD that was used extensively in WOCE and within this model it is different for each individual instrument but it is an anomaly around zero where there are actually two calibration curves essentially, so when you get to this area around zero, you can get quite a serious error in your calibration, in terms of a WOCE programme. We get round this by offsetting the zero somewhere so we end up with one calibration. We force the data and we then correct it all back 2 milli-degrees later on. An in-house check might miss that because you might do a couple of points and find that you have a reasonable curve, especially if you did not go down and work hard around the zero point.

In-Situ Calibrations - We had an instrument come into our laboratory, brand new and 70 milli-degrees out on its temperature probe, straight from the manufacturer; another example of no calibration. You pick up a new instrument you might think it was ready to go, (this is a bit of a worry as you think how many times do I have to have it calibrated before I am sure) but don't believe everything you see straight off the manufacturer.

This is the response time of a temperature probe (*Fig.4*). It should respond to a change from about 20EC to about 2EC in just under a second but these are two probes which came in from the same manufacturer brand new and then when we do this test by plunging it into a cold bath, the response time was 10 times what it should have been. It was of the order of 8 or 9 seconds and it turned out that there was air inside the PRT (Platinum Resistance Thermometer) which should not have been there, but again if you rely on a in-situ calibration, you might miss that.

Assuming that we think doing a formal calibration in a laboratory is a good idea, that is the rough schedule for a what calibration traceability is about - you have your instrument, it is compared for whatever parameter against a transfer standard and that transfer standard is itself calibrated against some primary standard which should be approved nationally or internationally.

Conductivity - the defined Standard is actually a Chemical Standard but is a physical measurement with Potassium Chloride solution as defined by The Practical Salinity Scale 1978. The transfer standard for that is Standard Seawater. People often ask me why don't we produce Potassium Chloride as the transfer standard and send it out to everybody. There are two reasons for that, the main one is that the temperature coefficient of Potassium Chloride is quite different from that of seawater. All your measurements are being made on seawater and so you always try to match your standards matrix with your samples and from a temperature coefficient point of view alone, it justifies that Standard Seawater should remain as the transfer standard. There is also historical link with standard seawater. If you are doing conductivity calibration, you need a high precision salinometer and a thermometer. Generally with a CTD you have to immerse the CTD in a water bath preferably using natural seawater. You need a thermometer because the relationship between conductivity and salinity is temperature dependent.

For temperature triple point cells in our laboratory we have Mercury, Water and Gallium because we work within the ITS90 approved scale and unfortunately for us really, ITS90 does not allow you to extrapolate from zero so if you do any measurements below a triple point of Water which is around zero, you should have your primary standard calibrated down to Mercury which is around -39^{o}C. It is unfortunate because most of us don't go below -5^{o}C anyway. Again, associated with that you need some sort of high precision resistance thermometer in the water bath in order to make comparisons.

These are nice fairly defined routes and nice accepted standards and as a result the comparability is, as Roy Lowry said this morning, for temperature and salinity within the WOCE data set, very good and some of the reason for that is the nice clearly defined traceable route. But for chemical standards it is not so easy. Nutrients is one I particularly wanted to mention because nutrients are measured generally by colorimetric techniques and up until relatively recently they were done by manual methods using pipettes and a spectrophotometer of some kind. The trend over the last 5 years has been to go over to autoanalysers which allow throughput of a much larger number of samples and perhaps arguably less operator involvement but the problem with that is that there has never been a good standard for nutrients.

I sit on a IOC Committee that looks at standard reference materials and nutrient standards has been a high priority on that for the last 10 years. Some laboratories are very capable at making up standards but the problems has been there has never been a standard in seawater and the reason why a nutrient standard is needed in seawater is there are affects particularly to do with the change of refractive index between freshwater and seawater which in turn affects the nutrient analysers and can give false signals. Particularly in the open ocean where relatively low measurements are made, this can be a big affect. So we took on the task of trying to produce a nutrient in seawater standard for nutrients and we were in good company in not being able to produce a natural one. IFREMER have tried and Oregon State University have tried over many many years but the main problem is producing a nutrient standard that it has a value that is measureable and it has a value that stays the same. There are all sorts of natural processes that take place in seawater which generally deplete nutrient levels.

I have to say that we came to the same conclusion after many years of tests and research, we were unable to produce a working concentration nutrient standard. Working concentrations for the open ocean being of the order of 1-5 micro-molar phosphate for instance. What we have brought out now (*Fig.7*) and it is attracting a lot of attention, is a standards kit which we feel (and we are getting good sounds from most people involved in nutrient analysis at the moment) bridges the gap. It is a series of concentrates made to 10 times the level you would normally want to make your working concentrations and these concentrates are made up in deionised water, so they are not seawater and then with each kit, or separately, we can provide water which we are now bringing in. Literally 1,000's of litres of seawater a month which is naturally depleted for the nutrients and the object of this is to mix your nutrient concentrates with the water just before you make your analysis. This is not a reference material but it is a working standard and a number of laboratories are using that to improve their data quality and to check their own standards measurements.

Finances - Relative Cost of Calibration

I have done some rough figures but they give you a guideline (*Fig.8*). What does it cost to calibrate a CTD? This is probably an underestimate but I have calculated as a general rule of thumb it is about £10,000 per day to put a ship to sea and I based the gear on 1% of its value which is a normal hire calculation. The price of a scientist per day and the price of a technician (maybe 2 technicians) came out at a total of £11,500 and I calculated the cost of calibrating a CTD as we would do a standard calibration at the beginning of the cruise and then a post-cruise calibration it works out at about £60 per day, which is about ½% of the cost of the cruise.

I think that one of the problems with calibration, for the people who hold the purse strings, is that they don't see anything coming back for their money except sometimes hopefully a certificate. They buy an instrument and they think it cost approximately £30,000 and now you want more money! We don't get anything back for it! There is a sales job needed for putting calibrations into the costings a bit more! The frequency of calibration depends on the stability of the instrument and it depends on the quality of the data and Standard Seawater is a classic example of that when used on a salinity cruise.

You talk to two different laboratories, for instance Woods Hole and Scripps. Woods Hole use a couple of ampoules of Standard Seawater a day. They have a salinometer in a temperature controlled container and they are confident that by using a couple of ampoules a day their salinometer stays stable for the whole cruise and they are quite happy with their salinity data and I am not going to question it either because their salinity data always look good.

In contrast to that you go to Scripps who have been known to put ampoules into their machine every 10 samples which is a huge difference but the Scripps philosphy is that with all the cost of getting out there, lets check the data all the way along the line and if you need to sift out bad salinity points or drifts in salinometers, all those sorts of things, the standards check all the data back. So there are two ways of looking at this.

Funding a Calibration Facility (*Fig.9*)

We have looked at the cost of having a calibration done for a cruise, so what would it cost to have your own calibration laboratory fitted out? One of the activities we get involved in now is putting in calibration laboratories for people. They come to us saying they want a calibration facility, what do we need and can you do it? It varies; it depends what level of accuracy you require for your measurements but as a very rough guide, you have got to be looking at spending £75,000 per year on your calibration laboratory. That is based on writing off the cost of the capital equipment over five years which is slightly longer than normal accounting practices. Calibration equipment tends to last longer and it does not become obsolete and if it is looked after it easily stays working properly. You are going to need staff and you are going to have overheads, you are going to have temperature controlled laboratories, etc. Assuming you are going to do 40 in-house calibrations a year, it works out at £1,875 per year . This may be slightly misleading on the commercial price because that is the price of a standard calibration but for WOCE you would want to be involved in a bit more detail and it would be slightly more expensive.

Advantages of having your own In-House Facility

First and foremost it is under your control. It is there when you want it and you have knowledge of your own instruments and you have used them at sea and you know all about the strange behaviours of some instruments. You can give yourself priority of timing if you have got a fully functional calibration facility, you can say "our stuff always goes through first!" You can use it for continuously monitoring equipment and you can carry out your own performance tests which can be time consuming. Performance tests are not the thing really for calibration facilities. If you have a fault or an intermittent fault on an instrument, you want to be able to set it up and go back and look at it every day for a month maybe. That is much better done in-house and it is always going to be available if it is a full time in-house facility. However, it is not always going to be available if your calibration people are going to be at sea for 6 months of the year.

Commercial Facility

Our Calibration Laboratory is independent in that we don't manufacture any instruments and so we can give you a completely independent assessment of whether we think an instrument is working properly or not. Most calibration laboratories will have a wide knowledge of instruments and the turnaround time ought to be quick but I suppose that sometimes it is not if 10 CTDs come in at once! Commercial facilities should operate a quality system and they should operate it properly. Traceability is important and there is no reason why you shouldn't have traceability in your own laboratory.

Counting the Cost of Calibration

High quality calibration is essential for good data quality. The cost of calibration is low when you compare it with the total cost of collecting your data and the commercial facilities can provide high quality calibrations at a reasonable cost. We did publish an article about how we calibrate to the WOCE Standard so if you are thinking of starting your own calibration laboratory I have some literature.

K G Robertson

Q You mentioned that people go to sea with their CTD instruments, and their salinometers, etc. and in a sense perform, or at least check, their calibration at sea and you said this was an expensive way to do it. Certainly, looking at some of our colleagues from RVS, yes we do that, we take a salinometer to sea and we have been known to take pressure testers to sea as well. Are you actually saying we are over doing it? If you put a good calibration into operation at regular enough intervals could you avoid all that?

Paul Ridout

A No, I am not saying that. For some parameters, bringing samples back is perfectly adequate rather than taking all your analytical equipment to sea. I think also it depends always on what level you want to work to. For WOCE you had to take your salinometers to sea, mainly because you wanted to correct the data while you were there. Therefore you were stuck with that but for a survey company, for instance, they probably don't need to do bottle stations at all, because they are working an order of magnitude lower in their requirements. Nordeen was telling us how he took a triple point cell to sea for very specialist reasons in his case but I don't think any of us would really entertain having to do that as a normal practice because the stability of the temperature sensor is very good but at the moment, with state of the art of conductivity sensors, you either have to bring bottles back and do them afterwards or take a salinometer to sea. What I was really suggesting was that it is not a substitute for calibration laboratory, it complements it.

K G Robertson

Q Most of what you have been concentrating on is clearly CTD and the WOCE calibration being the peak of achievement but you did say earlier and rightly so, that there are applications that don't warrant the WOCE standard, how do you cope with that? Are there a range of other standards?

Paul Ridout

A One of questions we get asked most is we would like this instrument calibrated, we don't need it to WOCE standard so it is going to be a lot cheaper isn't it? It isn't, because the time taken is almost the same and once you set your laboratory up, the only difference usually is you don't become more slapdash in your calibration just because it is an order of magnitude, or even two orders of magnitude lower in requirement. You tend to use transfer standards which don't have quite the same stringent traceability factors.

In terms of application, for instance, we are putting in a calibration facility in Venice in December. They have come to us and said quite specifically all their CTDs that they will be putting out are going to work to no better than 10 milli-degrees. So we will put together a set of equipment and a procedure which will reach that level. If they want a lower than that level they will still use the same equipment and in some ways maybe over-calibrating it to a certain extent but it wouldn't be any point in putting in a whole new laboratory in that respect. What you shouldn't do either is put a WOCE specification laboratory where you don't need a WOCE specification laboratory, because it becomes expensive in terms of the equipment you need and the operational standards that you need.

K G Robertson

Q A possible extension of that is "let's have our instrument calibrated to a WOCE Standard and we won't have to do it so often?"

Paul Ridout

A No, because of instruments drift. Most manufacturers we come across say "How often do we need to have this CTD calibrated", this is a classic question. Salinometers too. The immediate answer is you normally have it done before very cruise. Some survey companies say those instruments don't do anything for a year and then it goes out on a trial. The general rule of thumb we get from most manufacturers and this includes servicing as well as calibration, is about once a year. I would be interested to hear what the Sea-Bird view is? Do you have a frequency pattern that you expect to see your CTDs back?

Nordeen Larson - Sea-Bird

A Yes. We believe that when people participate in cruises such as WOCE that it is important to calibrate all our equipment before and after the cruise. It doesn't make sense not to do that. If you are just going to check the health of the device as it sits on the shelf, once per year is fine. So if pressure sensors are drifting at decibars per year and our new strain of temperature sensors drift milli-K per year and if they are healthy, you don't need to check them more often than once a year. Conductivity is always a problem, its hard to get it right off the shelve and it is subject to drift in the ocean.

K G Robertson

Q You quite rightly said that CTDs are not just CTDs any longer, are they? Somebody this morning mentioned "Xmas-tree" and they do tend to get that way. There are oxygen sensors and irradiance sensors and those kind of things which are more difficult and more unpredictable and more awkward to handle; do you get asked could you calibrate an oxygen sensor?

Paul Ridout

A We do oxygen, pH, florescence, currents, wave heights, that are all relative measurements which are extremely difficult to calibrate. As there have been over 10 years of appeals for a nutrient standard there ought to be now another 10 years of appeals for improvements in calibration facilities for all those parameters and for anybody who is listening from the EU, that is where the money should be spent, on trying to harmonise the calibration procedures for those difficult parameters. They are being measured more and more in the oceans but the calibration procedures have not moved along either with the volume of data requirements that are now coming for those measurements, or with the instrument development.

Instrument manufacturers are producing more and more sensitive instruments, particularly optical instruments but no one is addressing the calibration in a real sense and that is trying to recreate field conditions in the laboratory when you do your calibration. There have been many instances where calibrations have taken place in the laboratory which have come unstuck when you get to the open sea because they have no bearing. A classic example is one of the major CTD manufactures produced a CTD that calibrated beautifully until you put it in the ocean. Brilliant in the calibration laboratory but the deeper it went, the worse it got and it turned out to be a pressure related effect and you can't always recreate that.

Nordeen mentioned this morning about the difficulty with using artificial seawater compared with real seawater and small differences which we find sometimes on the conductivity side. We fine tune this but the chlorophyll and dissolved oxygen sensors are not very stable and so there are problems there. This is an area which really needs seriously addressing.

K G Robertson

Q I guess you would suggest that is one of the ways in which Dr. Kramer's criticisms this morning might start to be answered if there is some co-ordination there.

Paul Ridout

A There is no need for a standard, there is not going to be a Fluorescence or Chlorophyll standard. You can buy Chlorophyll now from known laboratories, it is the methods and techniques. Even if you never come up with a defined method at this stage, some comparisons need to be made on how different we are doing things in Europe to try and come up with a calibration protocol in the way we have got protocols for measurements from WOCE. The calibration certainly for those parameters needs to be looked at.

K G Robertson

Q Roy Lowry said there is only one right way and as many wrong ways as you chose. The item Nordeen mentioned about calibration before a cruise and calibration after, I would like to hear your comments on that? If there is a difference between the two and I suspect there very often is, can you from your knowledge of the instrumentation, assume that a certain process has taken place and effectively linearly interpret between the two? Is it a safe thing to do?

Paul Ridout

A You have to know what you are doing and I am not quite so sure about CTDs but in terms of whether you are looking at a gradual drift over a cruise or whether there has been some sort of step change during the cruise and you have to go back through the data and look at notes - the more notes people take the better because you maybe able to tie that down to some incident - a change of sensor being mentioned this morning. We see it with salinometers and salinity bottle runs. People make notes, hopefully, on the Log Sheet and then you run a standard ampoule at the beginning of a salinity run and you run one at the end. If the one at the end has shifted by 0.002 in salinity from the one in the beginning, which would be a big shift, you then have to go back through that data set and decide whether you can see a step shift in the analysis and you can confidently say there was a shift in calibration at this point, or failing that, if you can't do that, you end up averaging the error over that range.

There has been a huge change and WOCE has done this too. When I first went to sea I walked from the Chemistry Laboratory with nothing to do one afternoon and suddenly I was doing salinity. "You aren't doing anything - you can do the salinity." That is how it used to be. Photographers, Radio Officers, anyone would be stood in front of a salinometer and that wasn't uncommon. You were given a bit of instruction. WOCE has really upped the level of awareness so you have to know what you are doing and that highlight the importance of running the pre- and post-cruise checks and calibrations so that you may be able to monitor drift or step changes or faults. It gives you some independent measure of quality of the data.

K G Robertson to Dolly Dieter

Q In addition to the WOCE Specification, which is a very high one, are scientists in the US required, as part of the grant, to ensure certain standards are achieved or are there no restrictions like that?

Dolly Dieter

A I don't think there is a dead set rule that all of our funding, or awards, or grants require that a scientist calibrate his equipment. Where that comes in is in the review of his science and very quickly this is weeded out if this data is or is not being calibrated well enough. The big programmes, the JGOFS, WOCE, GLOBEC, TOGA - that is just part of the process expected. The core programmes individual is weeded out with the peer review. Needless to say, scientists cost money so if they can't get it from the agency, they are going to cut corners.

K G Robertson

Q Nordeen - do you have anything to say about the situation where pre- and post-cruise calibrations might differ a little bit and can anything be assumed between the two, as I am sure many people have been in this situation.

N Larson - Sea-Bird

A When it really counts I would never assume it drifted linearly between the two end points and that is the whole point in trying to make ancillary checks at sea. If the data are important you will make ancillary checks at sea and I think one of the most effective things to do is to put redundant sensors on your CTD. If you have two temperature sensors and two conductivity sensors making measurements at sea you can check on a real time basis whether something is going wrong or not.

The two temperatures must agree at milli-K level all the way down the profile. The two salinity measurements will agree at 0.001 or 0.002 all the way down the profile and if they don't, something is going wrong and you can catch the problem in a single profile, then go back to bottles and look for the answer and that is the whole point of running bottles, otherwise you just trust your CTD.

K G Robertson

From what you have just said, I can immediately see the damage of a linear interpolation between a perfectly calibrated instrument and a totally dead one!

P Ridout - Ocean Scientific

A I agree entirely with redundant sensors and that applies in the calibration laboratory as well. You never really can rely on one transfer standard so you always have two or maybe even three. The 70 milli-degree shift that we found in one instrument was always because they did not put a redundant sensor in the calibration tank, otherwise they would have picked that up straight away. Someone had damaged the transfer standard unbeknown to them. The idea of redundant sensors is important.

The way things are going autonomous vehicles, long term moorings, the GOOS programme particularly are going to require instruments that can stay on site for periods of years without calibration and that is where standards will become important because you are going to need internal standards to calibrate the instruments with, maybe even operating a calibration remotely by some satellite communication link. It is the way things are going to go but there will be fundamental problems which have to be overcome, biofouling being one of them and the most difficult at this stage. Long term deployments with instruments to stay in calibration much longer are definitely the requirements of the future.

K G Robertson

Q I don't know how many people here are aware of the GOOS programme. It is a global thing as Paul has suggested just now, a system that is designed in concept to run with the absolute minium of attention, to monitor in different parts of the world, in different parts of the oceans of the world for different purposes. What is monitored in one place might be rather different from another but with the absolute minimum of human intervention, perhaps dumping data via a satellite to a ground laboratory at frequent intervals. The lack of attention is going to put great demands on stability and initial calibrations and it is going to bring about developments in sensors that we don't know about yet.

Autonomous Underwater Vehicles, or AUVs, are quite topical at the moment and the other group that Dolly Dieter is involved with has a special working group today discussing certain aspects of autonomous underwater vehicles. Those of you who are able to come across to SOC on our short tour may have the chance of seeing a system called AutoSub which is being developed at the Southampton Oceanography Centre. This will explain itself when you get there but it is a suite of vehicles that are designed to do some magical things. The initial concept was that you could drop one of these things in the water in Falmouth UK and it would turn up in Falmouth, Massachusetts outside the door of Woods Hole and in between it would have measured a whole load of parameters across the Atlantic, avoided the odd yacht and supertanker on the way and down loaded its data to the satellites on the way. A tremendous project and it is very, very, ambitious indeed but this is something that will not go at enormous speeds and will be in the water for a long time possibly and the quality of the data needs to be as good on "Day Z" and it was on "Day A".

P Ridout

The widespread use of Autonomous Lagrangian Circulation Explorer (ALACE) Floats in WOCE as well. They are projecting ALACE Floats will go down for 5 years now and if they are carrying conductivity probes they have got to do something about that first.

K G Robertson

Q Has anyone here experience with landers because I know the NIOZ people are quite advanced with some of these things. As I understand it, the intention is that these instrument systems are put on the seabed for extended periods and asked to perform their data collection and analysis for a long time, largely unattended, certainly in terms of performing calibrations on the sensors?

A. I am speaking as a bystander and I know experience up to now has been sad because of malfunctioning of the instrument and the broken conductivity sensor that was pre- calibrated but it came up broken so it was useless to post-calibrate it. It does pose a great number of problems and the demands of the scientist really are challenging in respect of the amount of time that you can really trust the sensor. We were thinking of having multiple sensors in order to get statistics on that, although common factors like ageing won't come out, perhaps throwing in a new sensor every now and then, these are just thoughts on how to maybe check the problem for long term deployments.

P Ridout

A Instrument manufacturers are making instruments that are more and more sensitive and scientists are requiring instruments that stay on moorings or on data buoys longer because of the expense of putting ships to sea. It is a more viable option for them to do that and I am not sure if the two sides are coming together at the moment in terms of their requirements. People are looking at things like battery life because battery life obviously becomes important if you put an instrument down for a long time but bio-fouling and other aspects of long term deployment need to be addressed.

A. We are at the very brink of what is happening down there in the ocean and perhaps 20 years from now we will look back and say this is ridiculous what we were doing then, but I think it is hard for anybody to get a grip on how to attack that and what is really crucial to do and to not do!

P Ridout

A I think there is some work going on at SOC regarding anti-bio-fouling coating materials and looking at making sensors from materials that are less prone but it could be a long time for this happens.

A. Looking into sensors and going into sensor workshops teaches you a great deal about sensor development but how about putting it into 600 atmospheres and salt water and they start laughing, saying this is something special and in fact if there was a way to turn around the problem, it would be to have every manufacture develop for deep ocean, then it would be suitable for the rest of the industry but they don’t. I think we are the most demanding and such a small market share that there are not many companies willing to put a lot of effort in.

Dr Kramer

A A comment on the use of floats, buoys, etc., in fact any unmanned device which is collecting data, not for days but for weeks or longer. I think at the moment the data comes out in a different quality than the data measured on site or from collected bottles. There is an intrinsic value in a very long series of data to know what is the effect of a storm for instance in a certain event. You should never treat data now or in the next 10 years as post-quality data because it will not be realistic to develop over a few years.

Mr David Ayres

Isothermal Technology Ltd, Merseyside

NOTE - Much of this excellent and entertaining presentation was practical demonstration and the verbatim text is given here as a reminder of the content.

We are based in Southport which is North of Liverpool and we make most of the world's national standards. Most laboratories you go to throughout the world have our equipment, in one form or another. I work in the NAMAS laboratory so I am a practical person, therefore I have brought things along to show you.

I thought I would bring something that is portable because it is 'ships' and something that is accurate because talking to Nordeen he was talking milli-Kelvins, and I come here and you talking sub-milli-Kelvins. I have brought you some small cells and the company philosophy is that if we can't sell you a big thing then we will sell you a small thing, or something! A lot of developing laboratories and countries can't afford £1,000's but they can afford a few £100 and we have made up things that are a third of the size and two-thirds of the price and we do what we call 'slim cells' which are very portable and fairly robust. The smaller the thing the less chance it will get broken and we do a range of furnaces that go with it. I have brought the smallest one which goes from about -20EC to about 75EC and you can do fixed points in it and comparison calibrations.

I have got a volunteer called Steve who works in the lab. and I am hoping this is going to work. We are going to do the 'slush' method, performing a triple point Water cell. "Slush" for the translators is like watery snow. Basically, I have supercooled the water, it is still water and is waiting to go into ice. Being such a pure sample it hasn't got the impurity to form an ice crystal. The way you do it is to take the cell out and give it a flick and the shock is enough to send a cascade of ice forming down the bottom.

If Steve would like to go to the middle of the room, we will demonstrate how easy this is to do, to get to within a milli-Kelvin or two in a room like this. If you look carefully you can see it is still water and give it a shake and it goes through. What we normally do then is put that back in a bath at -7EC and then leave it there for about ½ hour to form it better and then put some warm water in and here I have water about room temperature and you slide a bit in and that melts the inner part and the ice mantle now is free to rotate. If you bring the bath up to 0EC pop that in it and you have a Water triple point.

The joy of fixed point cells is they are generally easy to operate but like all measurements you need more than one because here is one from the National Physical Laboratory which has a certificate but which is no good and the way you tell whether you have a good Water triple point cell is that the top part is under a vacuum and if you move the water around in it, you get a clunking noise. You need some means of checking what you are doing is right. Water triple point is the most fundamental point in the temperature scale, it is 0.1E by definition it will always be there.

Another demonstration - the "Hyperian" needs electricity to go positive and negative in temperature and this won't last long but we have this device that uses Peltier units which are fascinating things, like a reverse thermocouple. With a thermocouple, you put heat in to get electricity out but if you put electricity in, you get a funny effect going on. A thermocouple has a hot end and a cold end and if you imagine that you put electricity in, then you get a hot end and cold end forming, which is called a Peltier. It consumes huge amounts of current and if I start here it might make it to the end. What you have to do is to pinch it between your fingers you should feel one getting very hot and one getting very cold.

The other thing that you should never do is to do an unproven demonstration - so Nordeen and I are going to do this - here we have a slim Gallium cell which melts at 29.7646EC and if I put it in my pocket it will melt and I have a fixed point to a milli-Kelvin in my pocket. But I am going to go one better - we are hopefully going to form a Gallium melt point. I have a flask of water here at about 40EC and if I pop my cell in there it will start to melt. We are going to put Nordeen's super thermometer in there and we will argue who is right! I have popped it in the water.

KGR - when you say it will begin to melt - what do you mean?

A melt point cell is reasonably easy to understand in that you get something that is relatively pure and when it melts it holds its temperature constant, so you pour heat in and it just goes to melting the substance and the temperature remains stable.

I think triple points are a little bit harder to understand and if you are interested in the description of a triple point, it is one which proper thermometerists laugh at! I can give you a physical idea of a triple point first. If you can imagine you are a mountaineer and you want to make a cup of tea on a mountain when you come to boil your kettle you find that the tea you make is poor because the temperature of the water is low, which demonstrates that pressure changes boiling points. You reduce the pressure and the boiling point goes down.

The other concept is that if you can imagine ice skaters - a skate going across ice, the pressure of the weight of the person on the skate is on a knife edge on the ice and that pressure causes the ice to melt, so if you reduce the pressure above ice then the melting point goes up. So take ice and keep reducing the pressure on it and take water and keep reducing the pressure on it and sooner or later the melting point and the boiling point come together and that is a triple point. What it actually is, is all the phases of an equilibrium so that water to ice, the ice to water, water to gas and gas to water, are all balanced and that in a water triple point cell occurs at the surface. Nordeen was saying earlier that he has actually measuring 29.7643E because as you go down, you have a pressure of water and that changes the temperature and so where the thermometer is registers a different temperature to where the surface is and you have to correct for that and at Nordeen's level he has to make very fine corrections. This happens to all fixed point cells so the Mercury triple point is about 1 milli-Kelvin and the Gallium is 0.3 of a milli-Kelvin. A melt point cell is ideally you keep the pressure about 1 atmosphere and you have a solid ingot of something like Zinc, you apply heat and it melts.

Now for the ITS-90, the temperature scale that came out with redefined values for the fixed point, you take the freezing point rather than the melting point. In practice they should be the same but due to influences of equipment that does change.

Are you happy with the concept of temperature and what it is that you are doing? If you read any physics book and look up temperature, very few give a good definition. The way I look at it is - it is the amount of energy in a system and that energy is seen as the atoms in a lattice vibrating the electrons in the outer shells, moving around, jumping position and when you take that energy out, all that starts to slow down, until you get to the point of no energy where all the electrons are in their lowest shells and that is absolute zero; you can't take any more energy out because there is no more in there. You are into the atomic energy and the definition of the temperature scale is that the theoretical temperature scale is absolute zero and then you draw a straight line as a temperature scale and you need another point and this is a Water triple point and that would be at 0.01EC or 273.16E Kelvin - and that is a theoretical scale.

The trouble with us practical people is we have got to try and realise that, so we make these attempts to build Water triple points and also to put other points on the straight line and that is where you get the International Practical Temperature Scale of 1968 which has just changed to the International Temperature Scale of 1990. They have removed the boiling point of water and thrown away melting ice because it is not accurate enough when you have people like Nordeen pushing the limits and us as well. He is at the same sort of level as we are in trying to get better temperature measurements. Boiling point of water on the old scale was artificially held at 100E and now it is 99.975E, so the values that you assign to these funny points change with time because people can make better methods of measuring it and better artifacts that go in between the fixed points. You haven't got an infinite number of fixed points and these bits on the straight line, you have to somehow join them and use these things called thermometers.

ITS-90 says that from about -200E up to 962E, the melting point of silver, that you use a Platinum Resistance Thermometer. Nordeen can replicate a Platinum Resistance Thermometer with his thermistor by doing a lot more points and fitting a curve that will exactly fit the Platinum Resistance Thermometer, the official instrument, hence the difference between primary and Nordeen's thermometer. To all intents and purposes it is a Platinum Resistance Thermometer because he can curve it.

The concept traceability says that we should all work towards having our Standards traceable to the National Standard. In temperature it does not work, as we are finding out, because we have got to a point where our National Physical Laboratory has been privatised and they are in direct competition with us. We are the best N.S. Lab in the country and our national NPL are having to get N.S. now to operate under this scheme, so we are saying what gives them the right to say they have a better Zinc cell than we have, for instance? We can make Zinc cells equally as good as them. What we are saying now is, you have two types of traceability - you have traceability to your National Standard and you have traceability to ITS-90. We can say that we can make cells that will give you an uncertainty within a few milli-Kelvins of ITS-90 but it will also have an uncertainty probably greater to your National Standard, because to trace it to your National Standard you have to have some sort of route that involves thermometers and transport and we can demonstrate by various measurements of the curved shapes of these freezes and melts on cells, the purity of the metal or water and this is what Nordeen and I have been discussing, how he can show that his fixed point cells have a better accuracy than the calibration, really doing physical measurements on the materials to show that to all intents and purposes they are pure so they must be producing the temperatures that we say.

One of the points that came up earlier was the how often do you calibrate things? When we are asked that question I say you have to refer it back to the calibration history of the device and the importance of that device. If you are in the food and drugs industry and you are making something that kills people, then you build up a strong calibration history of the device before you actually use it cure people and that can start off calibrating it weekly, monthly, whatever. You get the history and you can say well its drifting at a milli-Kelvin per month and we want to hold that, so we calibrate it monthly.

Some of our standards we check after every measurement so it does a measurement and then goes back into the Water triple point cell. For normal ones, it is once a month. Resistances once every two years because that have got a very slow drift. We always try and build in over-determination that if you calibrate a thermometer at fixed points, ITS-90 describes how many fixed points you need for a range, but a map will fit any curve at any point, there is no way you know whether it is right or wrong. If you do another point and see if that fits on the curve, again as Nordeen does on his - he does 11 points and fits it to 5 or 6 - and then check the other ones are on the curve. It gives you a nice warm feeling at night to know that you are not killing people! We deal with Nuclear Power Stations, Drug Companies and a lot of the important industries come to us for their standards.

We build self-calibrating thermocouples and what we have done is that if you can imagine that is gold, if you then put your thermocouple in there and seal it in there, that is your thermometer. Drop that into a furnace and every time it goes through the gold point you will see a plateau on your temperature readout and you can confirm whether it is right or wrong every time it goes through that temperature. So if you imagine your deep sea thermometers, you could envisage having the super thermometer encapsulated in the Gallium cell with heat around and then every now and again you apply the heat and watch the readout go through the plateau and its melt point and you have a self-calibrating thermometer. Electrical measurements are easy these days, there are so many stable resistors, the electrical side is easy to sort out, but there is still this fundamental fixed point business.

This is Nordeen’s computer interface but at the moment it is 30.010559EC and we have put warm water on the outside of the Gallium cell and the solid part of the metal is melting in and we have also got warm water on the inside and it was much too hot, about 40E to 50EC. It is cooling down and that heat has been transferred into the cell and with any luck, in a little while, at the 29EC barrier it will settle down and we will have a little short melt and it should come to 29.7643EC.

It is really a demonstration of the user-friendliness of freezing point cells, it is relatively easy to get high accuracy from them without a lot of cumbersome equipment. Once you go into comparison techniques, there are two methods of calibrating:

Fixed points which stay at the right temperature when you pop your thing in and you know it is that temperature.

Comparison is where you have some sort of isothermal volume such as this aluminium block in this furnace that you put some sort of thermometer that has been calibrated, say in the fixed points and put in an unknown like a thermocouple and then you can compare the readings of the two thermometers.

For comparison readings you need an isothermal volume, some thermometers and some calibration. Fixed points tend to be easier in terms of maintenance and user friendliness. Anybody can do a fixed point calibration and get a number and know if they are right or wrong. It takes an expert to use a metal block pile because you don’t necessarily know is you are measuring right. A thermometer will always measure its own temperature and you just hope it is the same temperatures as everything else. Hence this business of these units you have been looking at, the thermometer is happy to read anything you like to put it in, but the first thing it is going to do is read its own temperature.

K G Robertson

Q How long can that stability be maintained?

D Ayres

A In the big cell - 12 hours. We try on the big systems to get a working day out of anything we build. To the point that you can automate it, put a timer on the bath, switch on and when you come in, it is ready to use. The small stuff, you are going to get a day's worth if you are lucky, so ½ a day is for those people who have only got a few thermometers and just want to check them now and again; like on board a ship. It is a simple, independent way of checking something if you have got total confusion in the system. We always use the Gallium point as our over-determination point on everything we do. We do Water triple point measurement and resistance, Gallium point resistance and then you can fit a curve to those two points. If you extrapolate it all the way up to 962EC you can be very close to the real reading, so if you made a mistake somewhere, you could pick it out like extrapolating the Gallium point which you put back on the curve to see if it fits. You can use it two ways to check that you have got the right numbers and if you haven’t it will show you which one is wrong. For this we use software.

K G Robertson

Q This technology has been known about and used for some time now. Is there anything happening to advance even further; are there new standards being considered or conceived right now?

D Ayres

A Yes. It is improving on what we have got and being able to take a freezing point cell and prove that it is what it is, other than putting a thermometer in and in a documentable way of doing it so you can see it on paper and prove it with graphs. The actual practical bits - we are always making new types of thermometers. Everybody steers well clear of the new surface temperature measuring device because there is no such thing as a surface temperature really. It is some sort of interface that moves around and you are always chasing numbers as soon as you put a thermometer on to the surface, it disturbs the surface and it is not the same any more but we have got a little thing now that when you put a zero heatflux thermometer. It senses the conduction up one arm of a thermocouple and then beats heat back down until you get a zero difference of temperature on the probe you put on and if there is any heat going up or down the wire, it must be at the same temperature as the surface, but there is no international standard and there is no NAMAS laboratory that is accredited to it. There is only one company in the Netherlands who are anywhere enthusiastic in doing this work. So we are the only people in this country that are interested because it is not something you can easily make a standard on. Surface temperature measurement is used by so many people - popping things onto pipes, etc. that is safe, that is fine, that’s at 200^{o} C! These things are often miles out. Different types of thermocouple combinations are used, like Gold and Platinum but gold plating thermocouples gets a bit expensive.

K G Robertson

Q Pressure effects were being discussed this morning and you must be aware the pressure has an effect on the sensor. Somebody said “what is the physical effect?”

N Larson

A We think we know the answer but it is not provable yet. In the case of temperature sensors, our CTD temperature sensors are built with a thermistor down inside of a small stainless steel sheaf of equivalent dimension to a hypodermic needle. The rod thermistor bead has a pressure sensitivity itself of about 1 milli-K increase in measured temperature for every 10 metres of water of hydrostatic pressure. So the metal sheath over it is to isolate the thermistor beat from ocean pressure. We tried to put the bead in thermal contact with the sheath wall by having some sort of intermediate fluid, a thermal grease that we use and the idea then is that under deep-ocean pressure that the metal sheath will collapse down a little bit, but there will be a gap in there to prevent the sheath from collapsing down and contacting the thermistor bead. The grease then should just slosh around and provide no load or pressure on the bead but apparently some is getting through and the effect is very reproducible. If you pressure cycle in one day in a test bomb you get a measurable pressure effect on the temperature sensor which is of order of 1 or 2 milli-degrees in 6,000 to 10,000 metres. If you put the sensor on the shelf for half a year or a year and test it again you get the same number. I think perhaps it is the fine ceramic powder that is embedded in a good thermal grease which is separating and is granular and which is allowing some of the collapse of the metal sheath to be felt on the bead itself, but we are not quite sure.

In the case of conductivity sensors - conductivity measurement is made over a specific geometry of water, so really when you make a conductivity measurement in the ocean, the measurement is made on the specific cell shape. The shape comes out as a coefficient in calibration but if I can gloss over that, the cell shape is important and the stability of that shape is very important to the stability of the conductivity measurement. Anything that alters the shape of the cell, where the electric fields are that make the conductivity measurement, alters the calibration, so a very clean conductivity cell put in the ocean, which begins to coat with some minerals, calcium carbonate or such, then that coating has the effect of altering the shape. That is where most of the drift in conductivity cells comes from. Bacteria grow and mount on the inside of the cell and cause problems. In a cell of our shape, one micron (1,000th of a millimetre) coated on the inside of the cell shifts the calibration by 0.035. In salinity that is a lot, although it hardly gives you a fringe effect in white light!

The point is when you put any material under pressure, be it metal, or ceramic, or glass in the case of our cell, the bulk compressibility of the material changes the cell shape under pressure, so you have to correct for that. Our glass conductivity cell gets smaller in the deep ocean. We use pure bar silicate glass and the bar silicate glass has a very reproducible compression coefficient and we just correct for that. The same as the Neil Brown cell uses 995 aluminous ceramic, it has it’s own compression coefficient, that is corrected out of the reading.

The electrical contacts in the cell are hermetically sealed on the outside by epoxy. When the cell was first designed we used an epoxy that was squishy, very compliant to pressure and so those early cells built that way felt full ocean pressure on the inside because the ocean water was just there. It also felt full ocean pressure on the outside of the cell because it was able to push through the compliant coating. The new cells are built of a different epoxy and the composition of the epoxy changed without our notice. The epoxy is strong so now full ocean pressure is not reaching the outside edge of the cell. The cell is not collapsing with the bar silicate compression coefficient any more. It is now a composite compression coefficient of epoxy and glass. We can prove this by shaving off the epoxy and watching the cell have a compression effect which goes back towards silicate, so now we are testing new coatings and I believe that will give us a more idealised cell. I think this is where the pressure coefficient comes from.

K G Robertson

Q David - You have introduced this little device (Peltier) and we know of the effect but what is the use of that effect in this particular application?

D Ayres

A Two of those, you heat and cool the metal block that is inside. You have current going one way and it will heat the metal block. You reverse the current and you can cool it, so you don’t need refrigerating devices. We do a bigger one than that called an Oceanus to take full size cells but that needs water cooling because you have four of those devices and you require a lot of power.

K G Robertson

Q Do many people here, or the Institutes and Organisations you come from, actually set up your own full calibration facilities or do you use something like Paul Ridout’s organisation - Ocean Scientific?

NIOZ

A We are building, not a full calibration facility, for temperature we do and we are quite a bit on the way. For conductivity we rely on the calibration facility from Sea-Bird and we buy our Standard Seawater here and for pressure we rely on two calibration facilities - so we don’t do it all ourselves. It is half-way.

K G Robertson

Q When you go to sea with CTDs, you take along salinometers and bottle samples? Sven Ober said that could include the triple point cells.

G W Miller - RVS Scientific

A I like the idea of taking a Gallium cell but the problems exist regarding transporting it by air. If the ship is in Southampton or another UK port and you can put one on then it is a good idea because although you keep track of salinity with the "Autosal", particularly with these WOCE type projects, it would be nice to keep a good track on temperature as well.

D Ayres

You only need one fixed point cell to determine if the thermometer has shifted but you need two if you want to recalibrate it. You can extrapolate to $^{-}5$ °C but it abuses ITS-90 but you are out in the middle of the ocean, so nobody is going to know!

G W Miller

Q I understand that if you put those temperatures into your practical salinity equation you'll get an error because is still relies on the older Temperature Scale, so people must be aware that if you are on ITS-90 you have to correct around about 30°, the top end of ocean temperatures and you are looking at something like 7 milli-degrees correction.

D Ayres

A Yes, it is something like milli-Kelvins at that temperature, going to 0.2 or 0.3 or even more at the higher end. Quite significant changes in temperature. A lot of people don't realise this and that there is new IUC751 industrial patent resistance thermometer. It is a completely different set of tables for that and thermocouple and not readily available.

G W Miller

Q Do you do any sort of training at your organisation?

D Ayres

A Yes, we do. If you spend £¼M with us we will train you for a long time; if you spend a few £100 you would get a few minutes, it is by arrangement. We don't have much of a sales force and what we say is if anybody is interested, then come to our NAMAS laboratory, bring your thermometers and we can play and you can see what we can and can't do. You can learn from our mistakes and see why we have burn marks on the bench, because we didn't put the furnace in properly.

G W Miller

I would like to say that information it is important that organisations like SOC. We have some sort of calibration facility, particularly for temperature and pressure. I also personally like to do checks on conductivity. If you are looking at getting WOCE Standards you might need to send your CTDs away but for a lot of our work we need regular calibrations and also routine tests on other sensors, calibrating thermosalinographs, etc. I think the idea that we can always rely on commercial calibration laboratories, even though they are very good, is not necessarily going to be the case in the future.

D Ayres

A There are a lot of NAMAS laboratories in the country, all doing temperature. I was saying earlier that we charge something like £250 to calibrate a metal block furnace, other companies charge £100. Not only that, they will come and collect it and deliver it and turn it round in a week for £100. You think "what is the difference" when from both you get a certificate and both will have similar numbers on them. It is really in the quality of the calibration. They have not got time to check it for repeatability and stability and they've got half an hour to make a profit - 45 minutes they make a loss. There are NAMAS labs and NAMAS labs!

K G Robertson

Q We heard from Paul Ridout about the WOCE Standard and I think Paul agreed that as far as the research scientist is concerned that is perhaps the peak of what is necessary to perform high quality science and achieve high quality data sets, etc. I do get the impression that companies such as yours and others of course, are not content with that and are striving to go further and further and further. There is, of course, competition, but if I say "what is the point of trying to achieve more than the scientist says is totally satisfactory"? Is there a simple answer?

D Ayres

A Because its there!

N Larson

A I agree **-** because its there! I came from a university environment. When I finished my degree work at the University of Washington I got out of turbulence and into sensors; they seemed to be easier than turbulence. I think there are many answers and I think from a commercial stand point it is not easy to develop sensors that work better and better and so in order to get on that development curve and stay ahead of the needs of the scientist, we have to be several years in advance in thinking about the problems and looking for ways to improve and looking for a method. Maybe it is an improvement to the device itself, maybe an improvement to the method of measurement. We have to stay ahead of that if we are going to not be 5 years behind providing something that is wanted. So that is one thing, and certifying that you have made an improvement requires you to be ahead of the game with calibration. The other thing, I think philosophically, Oceanography is an interesting discipline. It is one of the few places and temperatures is one of my hobbies, where part per million measurement in temperature makes possibly some sense. Ocean body temperatures are about zero degrees, 273EK, where 1 part per 1,000,000 is 0 .2milli-K and it is quite possible that when tracing volcanic plumes that some signals at this scale might be found in the deep ocean, down at sub-milli-K level and if we can provide a device to make those measurements, maybe the scientists can find it. I find that fascinating and exciting.

D Ayres

A We are always being pushed to supply better and better standards, plus the fact that it is a passion and hobby for us. We both have similar companies but it comes from the soul, this development of temperature standards. It is a nice way of spending the day and is to commercial advantage. Fortunately we are still the best in the world and there is a lot of competition out there so you can either cut your prices and undercut the competition or you can improve your measurements and the things that you sell, so that the competition is still behind you and that is what we have done so far.

Sven Ober - NIOZ

One of the driving forces to improve sensors and improve the calibrations of the sensors and improve the calibration procedures, is to gain speed and to cut down discussion times about measurements so you can go on with oceanography instead meteorology and that is just a matter of costs. Every hour on board that you spend on quality, on calibrations, on sampling quality; it pays off 10 to 100 times. If we do a lousy job on board the result is no data, only discussion, hence, no results!

Dr Geert-Jan A. Brummer

NIOZ, Netherlands

"Micro-/Meso- Plankton Sampling using the Hydrobios Multinet"

I am a scientist and a geologist by education, with a lot of biology included as well and 5 years ago I came over to NIOZ working with sediment traps, more or less in the capacity as a chemist. I know a little about all trades but not everything about those three branches of science. My talk will be divided into four parts:

1 **Use -** why we use the sampling gear?
2 **Construction -** about how it is constructed.
3 **Operation -** how it is operated?
4 **Future -** what is the future outlook of this type of open/closing net systems, including recent developments?

Use
This is a copy of the front page of a PhD thesis by Janneke Ottens (*Copy shown to the audience*) called "Planktonic Foraminifera as Indicators of Ocean Environments in the Northeast Atlantic". What you see here are the magnified shells of planktonic foraminifera - the diameter is about 0.4mm. These are the larger ones so they are pretty small. They are a relatively small group of zooplankton. They are unicellar and they live in the upper ocean worldwide, from the very warm tropical oceans to actually living in the ice of the Antarctic. They form calcareous shells and that is what you see in terms of the organic matter which was in there has been taken out and that is the special thing about these creatures. After they die the carbon shells sink rapidly down to the bottom and accumulate on the sediment. They do that in such vast numbers that the concentration of these shells in a cubic centimetre of sediment is about several 100,000. Half of the ocean floor is covered with ooze containing these things and they have been doing so over the past 120 million years which is quite a long time and they are still living, they have not become extinct as the dinosaurs did.

One of the properties of such carbon shells, consisting of calcium carbonate, is that it includes carbon as well as oxygen and these two elements occur in different isotopes. This is one of the main reasons why I got involved in this Multinet business and the most important ones are, first, ^{14}C radionuclide which decays with time until after about 30 or 40 thousand years there is very little remaining but over the past 30,000 years it has been used to determine the age not only of this particular bug, but the sediment in which it occurs. We use it for age dating.

The second one is ^{13}C, which is a stabiliser. The amount of ^{14}C in the shell is determined more or less by biological productivity.

The third one is ^{18}O. This is a stabilising isotope and its occurrence in the shells is determined by the ambience of the water temperature, salinity and ice volume. During the Ice Ages there was a lot of water stored into the Arctic and Antarctic Ice Caps and this has an effect on the oxygen isotope composition of the water and this is what you find back in the fossil record.

It would be very nice if we could precisely tell what kind of temperatures, salinities, volumes, productivities have been there with time, during the Ice Ages and during the non-Ice Age periods. You can extend this record back to 120M years. It has become recently very important too with regard to the Greenhouse Effect and trying to find out what happened in the past and use that to predict the future.

One of the things we need to know is where actually do they calcify; where do they form these shells because they are living in the surface mixed layer and the temperature may be much higher than if they live say 100 metres below the thermocline where temperatures may be 10^{o} lower and the only way you can answer that question is look at the recent plankton, which is basically a geological question, but we need biology in order to answer that question.

Construction
The consequence of that was we needed to have some sampling gear with the following requirements. These decisions were made in about 1986. First of all there should be plankton nets which are capable of providing

good quantitative numbers of these planktonic foraminifera shells and we usually conventionally analyse these in fractions larger than 125 micron so the net mesh may actually be smaller but not larger and their sizes range up to a few millimetres at most, so that gives about the size range over which we need to sample. Secondly, as far as towing is concerned, generally we need oblique tows if we want to cover the tropical oceans, which are deserts, with enough depth resolution. If we only have vertical tows and we want to have a relatively high resolution, then with vertical tows we would have too few specimens to do anything with it, either in terms of species counts or in terms of isotope analysis and the number of specimens that you need for ^{14}C analysis is about a few 100 specimens. For the other ones you need less but a few 100 is still quite a number. The next thing is we need actual multiple nets because if you don't have multiple nets, you put the net into the required depth and get it up again repeatedly and it will simply cost you too much time in terms of ship time and as we all know, ship time is expensive. The other thing is that when I got involved with this it was in a geologist programme and geologists look at sediment not plankton, so they don't really like you to be present at all. It costs too much time they think!

As far as measurements are concerned, we need a good depth control and working with wire and wire angles it is too inaccurate for our purposes. Secondly, we need temperatures because temperature determines the isotope composition. We don't need it that accurately, so we are not talking about milli-Kelvins here. Around 0.5°C will be OK but if you can get it better of course, it is fine. Salinity, same thing, about 0.2 requirements. A good control over the flow or the total volume which goes into the net so what we require generally in different environments is something between 20 and 300 cubic metres of water that need to be filtered in order to get enough material. Last but not least, the thing needs to be compact, not too large but robust for shipboard work and also for when the weather is not too good.

What we arrived at, at that time, was a net manufactured by the German firm Hydrobios based on what was called a multiple plankton sampler. This is the only good drawing I could find (*Fig.1*). It shows the net which can be used also for vertical towing and although we considered this possibility, we have never actually used it that way but we use oblique tows and I will show that in a minute with the slides. This gives you a kind of impression of what it looks like. The top part is a steel box 50cm x 50cm and depth is about 60cm. These are the nets, 5 in a all, with 5 cut-ins at the end. Over here is the motor and the electronic parts.

Operation

The net works as follows. There is an inside which can be folded to the sides and the nets are zipped on to it. What happens then is that there are a number of these levers and elastic bands (*Fig.1*). This is in the open position and the top one is in a closed position. They are fixed to a crankshaft with release notches. There is a motor in which turns a rod to which the release cables are fixed and the motor can be activated by a deck unit which turns the shaft on which it is fixed. Then the thing comes loose by the elastic band and the net opens. For the next net you give the same command, then the previous net closes and the next net opens, so it is a sequential operation and in this way you can either obliquely or vertically open and close 4½ times, because the last net will remain open. This is usually the shallowest net. The operation is that you lower the net and then open the first net and then sequentially open the other nets until the whole thing surfaces.

I am a scientist not a technician and I am a user of this equipment. I have only been involved in analysing the samples myself long ago and then I got into the sediment trapping business because when you are on a cruise as a scientist doing sediment traps then the activity is only for a few days and for the rest of the cruise, you actually don't have any job but since I have the experience with these net types, I am always asked to do the multi-netting as well, so I ended up doing that for quite a number of years.

This is what it looks like (*illustration not available for this report*). It is different from what you saw on the few graphs, for several reasons and these are actually operational but we have modified the net in order to improve its performance, so this again is the net box, here in the closed position shortly before the whole thing goes into the water and before we start fishing. It also has a depressor which is needed to keep the net in a relatively horizontal position during fishing. There is a weight bar added to it as well and one of the major modifications that we included is actually this cage. This was born out of necessity and there was a place in the North Atlantic ocean in 1986 where this net was used. What happened was that during the upcast, for a reason we don't know the cause, the nets came over the box got themselves into the wiring on top and as soon as we pulled it out all the nets were torn to pieces and three of them could be thrown away. One was so severely damaged that it was actually beyond repair. Another had holes and tears in it and was not actually useful at all. These nets cost about $300 each, there are five of them as it is a multinet, so this is a pretty costly business.

The second thing which was quite a problem was that we put on a second set of nets and lowered it at the same place and tried the whole thing again and had the same result, so that was another five nets. By that time we simply did not have any nets left, so this could not go on.

In 1986 we decided to go to the net station; we would get all the nets repaired as far as we could and continue fishing. Everything went alright and it was going from North to South with no problem at all. In 1988 we returned and exactly at the same position, the same problem happened again. Now we really had to do something about it, so we shipboard manufactured a box around it simply to prevent the nets from going over the box and being destroyed. There were some tryouts before that. One of them was to make a kind of loop and so a single construction like this but the whole thing came up in a twisted and bent way although it was steel tubing so it didn't work and we decided to make the whole box shipboard. That worked and actually, it appeared that in later years when we got more information and we tried to find out how this net behaves in the water, that it did not change the way the net was performing. That was something that I was anxious about, that it would change the behaviour of the net during fishing. Another thing that we had to use is a rope about 8 metres long with a crate or a bucket at the end. It helps to get the net in and out of the water, it also helps to stabilise the net while fishing. It is a pretty simple solution to otherwise practical problems that we have. As I told you this net is operated by a deck unit and joined by tow link.

This is the same thing from the back (*illustration not available for this report*) and again the net is in a closed position. Here is a small steel thing in the box itself which contains a flow meter and a propeller with magnetic ends which turns round and the number of turns is equal to a particular volume which goes through the box into the net so that gives us our flow in terms of cubic metres of water. These are the five cod-ends which contain the catch. The next slide will show you how the thing goes into the water just before we lower it to its actual depth. Improvements since 1992/93 include the way the net is connected to the cable and towlink in order to minimise the potential damage to the wiring. Also to keep it a bit more stable.

To give you an impression of the way that we use it, this is a profile (*Fig.2*) over a depth interval of 500 metres taken in the Indian Ocean. What is shown here is the volume concentrations which shows the volume of the catch per cubic metres of water. This is a more or less typical profile of the plankton concentrations that you find, so they are very high in the surface and very high plankton productivity and it rapidly decreases to a depth of 200 metres, to remain virtually constant over the rest of the range.

The initial five nets are made during a single cast and this is the second cast which covers the rest of the depth, so this is net 1, 2, 3, 4 and 5 remains open. So in this sense if you take a second cast, then a second cast would go from wherever you stop, therefore it covers 100 metres to the surface. This is a disadvantage for using it for deep casts unless this is the kind of thing you want to have. This is the kind of resolution that we want in order to document the distributional patterns of these planktonic foraminifera. It means having a relatively high resolution in the top and relatively low resolution at the bottom. If this had been a vertical tow then we would have in this interval from 0 to 12 metres, far too little volume to get enough of these planktonic foraminifera. So that is why we use it for oblique towing.

This (*Fig.3*) shows you depth of the upper cast covering the top 100 metres depth and the temperature is given by four curves. These four curves represent up and down casts. One, the small symbols, is the calibrated CTD measurements and the two others are the upcast and downcast data from the multinet itself. It is important is to have these temperatures, because you can decide at that moment where you want to open or close the previous net in order to sample the actual biological situation occurring at that specific time and place. The multinet temperatures that you see here are raw data, not processed. They require calibration which we usually do against the CTD data in order to get reliable results.

Initially it was meant to use the system independently of a CTD, simply because the geology cruises at that early time were not using any CTDs at all but as it turned out that was only for the first cruise that we had. After that there was a CTD so we could perform these kind of calibrations at any time. The sequence was usually a CTD first at every station and then a multinet cast and then proceed with the rest of the programme. One of the disadvantages of this net as far as these kind of data are concerned is that, as they explained to me, cost reasons and at that time an analogue signal to be transmitted to the deck unit rather than a digital signal and that creates all kinds of problems, which I consider as a disadvantage of the system.

Future

I am now coming to the future we are looking at. This (*illustration not available for this report*) is another multiple open/closing net type called the MOCNESS, more or less the same system. The differences are that this net contains up to 10 individual nets, so if something really goes wrong with the net going over the side, there are double nets as well which means there would be 20 nets on this whole system. The system also differs in that it has an mouth angle which is not as straight as with the multinet but 45º. The other thing is that the nets are not changed by the elastic bands but are more or less transported in an up/down fashion but also sequentially. The kind of thing that is being implemented nowadays with such net systems is that the amount of additional gear that is going on to these nets is increasing, so I would like to have on this multinet a fluorometer and an ADCP. It becomes quite an expensive system but this is the kind of direction in which we are going. The basic type of net is going to be retained for at least the next few decades. It is a proven system and it is actually the only way that you can obtain this kind of material for whatever analysis you want to apply. The example is for the planktonic foraminifera but you could use this for fish larvae as well. You could look at organic contaminants or inorganic contaminants. It is simply a sampling gear for sampling a particular sized range of plankton.

This type of net is considerably larger than the multinet and you can obtain it in the same size. This one has a mouth of 1 x 1 metre, so a full square meter surface area. Then you can also apply coarser nets for the larger plankton and we have the problem that they occur less frequently, so they are much rarer so you need a larger surface area in order to catch them and the second thing is that the larger the bugs get, the more motile there are and they have an escape response. They can see the net and avoid it!

B Boorman - SOC

Q How long are the nets in the water?

Dr G J Brummer

A If we do a shallow cast to 100 metres, the whole thing from the deck and back again on the deck is about 20 minutes. If we go to 500 metres, because the volumes that you want to have are larger, it will take you longer. Usually something in the order of 1 to 1½ hours depending on the circumstances.

Mr K G Robertson

Q I was interested in how fast you tow?

Dr G J Brummer

A We normally tow at a speed of 1.5 knots to 2 knots, depending on what kind of mesh that you use for the net, so the coarser meshes you can tow much faster. We conventionally use a 100 micron net but we also have used 50 micron nets. From 100 micron to 250 micron is about the range that people use but it has also been reported for 500 micron nets and 325 micron nets. We pay it out at about 30 metres per minute going down to the depth that we actually want to start and then pull it up at about 10 to 15 metres per minute, depending on the flow that we get into the net. Sometimes you have the current with you when you tow so then you have to do something about it to get more volume. If you have the current against you then you can do this pretty slowly and still get the same volume.

Mr K G Robertson

Q You mentioned that you pay out the system until it is at the required depth. I could ask what depth do you normally tow, but I guess there is nothing normal about this. How do you determine in a vertical sense, where you are going to tow the net in the water?

Dr G F Brummer

A This is a two-thing policy. We have a kind of standard depth that we use which is the shallow cast which goes to a depth of 100 metres with intervals of 100 to 75 metres, and 75 to 50, 50 to 25, 25 to 10 and then 10 to zero. We can change these depths, although we stick to these intervals and depending on where, for instance, the chlorophyll maximum is or when we see the nephelometer at certain peaks, then we adapt our schedule. Then the deep nets are usually from 500 to 300, 300 to 200, 250 to 100 and then 100 to zero upwards. The readout on the depth meter goes to 1,000 metres.

The problem is if you want to go to greater depths you have to guess at what depth you are, because the readout simply stops there.

Mr K G Robertson
Q You mentioned that the instrumentation is increasing and increasing all the time but the only thing I did not hear you say was any form of video. Is it perhaps one of the items that you do attach to the system?

Dr G F Brummer
A I guess we do that but for the size ranges that we are interested in, it does not make much sense to have it. For the larger systems such as the large MOCNESS it may be something useful.

Mr K G Robertson
Q Ben Boorman **-** if I could ask you **-** as you get very deeply involved in these things for SOC, what sort of instrumentation do you normally attach to nets?

Mr Ben Boorman - George Deacon Division, SOC
A Just standard; in the past it has been just temperature and flow. We have now gone over to nephelometers and transmissometer with CTD but mainly for the BRIDGE project.

Mr A Hartling - Bedford Institute
Q Can you explain how you use your ADCP data?

A. Dr G F Brummer
We don't use ADCPs in combination with the net system and the only thing I can tell you about this is that others did. What they used was a downwards looking ADCP which is used for getting a better estimate of the flow through the net itself. This is a kind of difficult topic in the sense that if you want to really estimate the volume accurately, you have to take into account that the net is towed obliquely, so working at horizontal/vertical, measurements of flow or calculations of flow are not really depicting the real thing.

Mr A Hartling
Q The ADCP data does give you back scatter strength, so it is a measurement of biomass as well.

Dr G F Brummer
A In that sense it would be a useful thing on board and then compare it with what you have in the net itself. That is what ADCPs can do, as such.

Mr K G Robertson
Q I don't know anybody here who is very experienced with ADCPs (Acoustic Doppler Current Profilers) and their use in biomass investigations. It seems to be more of an art in the hands of a few people than a definite science to me but I may be wrong. A number of people are experimenting and have been for a long time?

Dr G F Brummer
A You need to calibrate with the net kind of systems to know what you are actually seeing in the ADCP record.

Mr K G Robertson
Q John Dunn **-** You are also working in this field and we may see some on videos later**,** let's not prejudge that but are you in Scotland using similar systems and instrumenting them in the same way?

Mr J Dunn - Marine Laboratories, Aberdeen
A I relate to a lot of what has been said and we have been working on many multiple size nets and we worked with Doug Sameoto from BIO with the BIONESS system and we subsequently came up with LOCHNESS (all in the family of NESS) but we also have been experimenting with lots of packages and we intend that the next piece of equipment to put on our multiple net system is an ADCP system. At the moment it is cost that is preventing that.

On a regular basis we have fluorometers, transmissometers, sometimes two CTD systems and control systems. We have multiple net systems that take 110 plankton samples, 60 water samples and measure 9 other environmental parameters every 0.2 of a second if you want. It is a black art and you *fly by the seat of your pants*! If you have the money and if you have got good technicians you can do it, if you don't, then you are dependent on things like my colleague from NIOZ on buying something from the Americans or the Germans such as the Hydrobios Net or MOCNESS system. We considered the MOCNESS system but rejected it on the grounds of cost.

Mr K G Robertson

Q Equally important, since we are technical people, are the winches and the cables that are used. Do you in NIOZ have to use specially designed winches and specially designed cables, fairings, etc., or do you have problems with this part of the work?

NIOZ

A We are using standard winches and we don't have much problems and for cables, we just use normal electrical mechanical cable with no fairing and at those speeds there is no problem with cable or that you don't get your gear down from drag. Fishing at this speed is no problem whatsoever.

Dr M Bergman - NIOZ, NL

"A New Benthos Dredge (Triple-D) for Quantitative Sampling of Infauna Species of Low Abundance"

Infauna are animals living buried in the sediment either permanently or seasonally. Animals of low abundance are animals which have a density of less than one individual per square metre and those low abundance infauna are animals like adult bivalves, snails, crabs, lobsters, starfish, sea urchins and anemones.

It all started four years ago when NIOZ got involved in a project named IMPACT (*Fig.1*)**,** which was an EU Project on the Effects of Bottom Trawling on the Benthic Ecosystem in the North Sea and especially the effects of bottom trawling fisheries on animals of no commercial value like bivalves, snails, etc. The aim of the project was to estimate direct mortality of these animals due to different types of trawls and we wanted to follow a method in which we assembled the densities and abundances of those infauna animals in a well-defined area before experimental commercial trawling and also after the trawling. We also wanted to compare initial densities with the remaining densities of those infauna species. Therefore, we had to make a decision on a type of sampling gear, either the traditional box corer or a grab sampler or a fine mesh beam trawl. Each of those sampling gears are designed to catch a certain type of animals.

For the box corer the target fauna are animals living in the bottom and because the size sample of box corers and grab samplers is so small, you need 5 or even 16 samples to cover 1 square metre. The box corers or grab samplers are especially suitable to sample and to estimate the densities of high abundance species so lots of numbers and animals per square metre and those high abundance species are often very small. Many of them are between 1mm and 4 mm.

The fine mesh beam trawl samples species living on the bottom and we call them epifauna and because of the rather large sampling size of the beam trawl, up to $2000m^2$, the beam trawl is suitable to catch and to estimate the densities of low abundance species and those low abundance species are often larger sized.

Within this project, scientific interest and also questions from the Department of Nature Management were focused on longer-lived, larger sized species living in and at the bottom of the North Sea. They are interested in those larger sized species because effects of fisheries on those larger and older species are more radical and longer lasting than impacts of fisheries on, for instance worms, which produces several generations of new worms per year. These larger species, which often have a life span of 5 or even 50 years, are low abundance.

What we needed for this project was a sampling gear in between the traditional box corer or grab sampler and the beam trawl. We needed a gear which could sample animals living in the bottom and animals living at the bottom. Animals that were of low abundance and larger sized. So we tried and started to search in the literature for such a dredge but we learned that trawls and dredges are at best semi-quantitative for fauna living deeper than 1cm into the bottom and in this lecture I will show you a prototype of a dredge which is able to sample those larger size and low abundance infauna to depths of about 10cm. This dredge we have named the “Triple-D” (Deep Digging Dredge) and it was developed and built at NIOZ. I will also give you some results of a trial on reliability and I will give you some results on comparisons of sampling gears.

This is the prototype Triple-D 94 (*Fig.2*)**-** the first prototype we had. It is designed to cut a strip out of the sediment with a width of 20cm and a depth of 10cm. It consists of a pair of steel runners connected by a metal frame and there is a mesh cage between the runners. This cage is about 5cm above the seabed and in the front panel there is an opening to let epifauna and fish enter the cage. At the rear side of the cage there is a net with a length of about 6 metres. The inner net is rather fine mesh, 1.4cm stretched net size. The outer net is strong nylon and has a stretched net size of about 8cm. The whole thing has a length of about 2 metres, it is 1 metre high and the weight of the whole thing is about 700 kg. The length of the cage is about 1 metre, it is 70 cm high and 90 cm wide.

In the bottom side of the cage there is the cutting blade which has a length of about 1 metre and we can put in several different cutting blades. The towing speed is about 3 miles per hour. We tow at rather larger speeds to get the sediment washed to the hind side of the net. The towing force is about 1½ tonnes and the sampling size is between 10 and 30 sq.metres, so the length of the haul is about 150 metres, because the cutting blade is 20cm wide, the sample size is about 30 sq.metres.

Here is a detail of the cutting blade and how the sediment enters into the cage and into the net (*Fig.3*). The cutting blade is mounted at the rear side of the cage to make the transport as short as possible. The sediment is pushed upwards through the cutting blade and at both sides of this cutting blade are longitudinal and vertical strips to prevent sediment, including animals, escaping sideways.

We did a trial on reliability and especially we checked the catch efficiency of the sampling gear which is expressed as the percentage of animals present in the seabed which are actually caught by this gear. We published it in the Netherlands Journal of Sea Research and we carried out the experiments in a sub-tidal area in Dutch waters on a sticky soft bottom ground. We assumed that in a very damp population of infauna bivalve "Macoma" that the catch efficiency of the normal traditional box corer will be 100%, when we take in a stretch of 100 metres, about 45 samples and that the density of animals larger than ½cm is reliably estimated by the box corer and our test was that we compared the estimate of the box corer sampling with an estimate based on the 12 hauls with the Triple-D.

The Tables (*Fig.4*) show the results of the trial. The number of animals estimated per square metre by the box corer in 45 samples and by the Triple-D in 12 hauls. As you can see the difference is not statistically significantly different so they are more or less equal and one remarkable thing was that the variance in the box corer sampling was significantly higher than the variance was in the Triple-D sampling, which means that when you use Triple-D in sampling it is much more easy to find statistically the difference between two sampling stations or sampling times.

This figure gives the length frequency distribution of both gears and the frequency, so the percentage of all animals found in a gear which had a certain length. As you can see both distributions were strongly correlated. We concluded that the Triple-D was reliably sampling infauna in sticky grounds but we learnt a lot in the first two years working with this prototype in several projects and we modified this early prototype last winter, so we now have a prototype 96!

What we wanted was to limit the length of the haul to 150 metres, to prevent clogging in the net and therefore we had to make the actual haul of the dredge independent of the ship's activity and more precisely, independent of the ship's speed during paying out and fetching in the line, also independent of the speeds of the winches during paying out and winching in. A second thing was that we wanted was to perform during the entire haul the right towing speed of 3 miles per hour and we wanted to keep the cutting blade during the entire haul at the desired depth of 10 cm into the bottom. These requirements meant that we had to exclude the first part of the haul and we had to exclude the last part of the haul. We wanted to exclude the first part because in that part the ship is paying out the line and the speed of the dredge is less than 3 miles an hour over the seabed. We had to exclude the last part of the haul because the ship is fetching in the line and because the ship also has its own speed, the total speed over the seabed is much faster than 3 miles per hour and it will come out of the bottom.

Therefore, the solution of all these problems was to construct a hinged underside of the cage, which includes the cutting blade, driven by a pneumatic system. This is a general view of the latest prototype (*Fig.5*) and as you can see the skis are connected by a tubular frame which can act as a storage tank for compressed air and you can also see that the pneumatic system is controlled by a steering device which is connected to the counting wheels, which are measuring the length of the haul by means of a magnetic reed contact.

We also enlarged the dimensions of the whole thing so that the cage is now 1.10m and 1.30m wide and the length is the same, 1metre. We also put on the skis extra 700 kilograms of ballast so the whole dredge has a weight of 1½ tonnes and this extra ballast is important because we want to force the cutting blade into the ground, also into very hard sandy sediments. It is variable and we can also take off some of the weight. The cutting blades are not changed and the towing speed is 3 miles an hour. The sample size is also unchanged.

Initially, the underside of the cage is pushed up and the cutting blade is not in contact with the seabed. When the skis are running over the seabed the cutting blade is free of the seabed so animals cannot enter the cage and in this position the dredge is stowed during the first and the last part of the haul. However, it may be possible that epifauna and fish will enter through the opening in the cutting blade and therefore, we constructed a rotating flap which changes from one position when the underside is up, to a second position when the underside is pushed down and the cutting blade is pushed into the ground. The sediment enters into the net and the flap is opened. So what are the routine activities for a haul with this dredge? On board the ship before the haul the frame is inflated with compressed air and the underside of the cage, including the cutting blade, is pushed up by the air. The length of the first part of the haul in which the line is paid out, the desired length of the preamble, and the desired length of the actual haul, with the cutting blade into the sediment are preset in the steering device. The dredge goes overboard, the ship sails away and the line is paid out. The dredge contacts the seabed. During the whole preamble and during the first part of the haul, when the line is paying out, the dredge is towed with the blade up so there is no contact with the seabed and no animals are caught in the cage and in the net. Then the counting wheel counts. When the number of counts equals the number of the preset length of the preamble then the pneumatic system is activated and the underside of the cage is pushed down and the actual haul starts.

Then the wheel is counting also during the actual haul and when the number of counts equals the preset number of the actual haul then the underside is pushed up and the actual haul stops. The line is fetched in and the sediment is washed out of the net in the water column and the dredge is hoisted on board. That is the ideal situation.

The volume of the catch varies between 10 or 20 litres to about 200 litres. It mainly depends on the amount of empty shell fragments in the bottom and a normal catch would contain lots of bivalves, lots of star fish and there are also crabs, sea urchins and fish. The catches are sorted out on board, animals are measured to their length, classified and counted and as you can see, the range of animals that is caught by the Triple-D is quite different from the range of animals that is caught in a normal box corer sample. There are many small worms in it and small bivalves only a few weeks to a few months old but there are only some larger animals in it.

This fact is also illustrated in the next table which is a comparison between a Triple-D and the box corer catch and on the first table (*Fig.6*) we took in a soft bottom offshore area oyster grounds, 5 samples with the box corer and 5 hauls with the Triple-D and when the box corer samples are sieved with 1 mm holes, you can find a lot of species. There are 42 species in it and over 2,000 individuals per square metre.

When you sieve the same 5 numbers of box corer samples over a sieve of 5mm you only find two difference species and strangely enough, a lot of individuals per 100 sq. metres. However, I have to say that this number (333) depends only on one individual in one box corer and this points to the problem of box corer sampling with larger size animals as a target.

In the five Triple-D hauls we found a lot of species and also quite a number of individuals per 100 sq. metres. This feature is also found in a lot of other locations, for instance, these are two sandy-coastal locations and two silty soft bottom offshore locations and we compare here 5 box corer samples with 5 Triple-D haul for species larger than ½cm and what we see is that the total number of different species in the box corer is far less than in the Triple-D at all locations.

The number of species in the box corer is about 20% of the number of species found in the Triple-D and of course, if you take more box core samples then you will find more species. Especially on soft bottom ground, you have to take a lot of box corer samples to equal the number of species found in the Triple-D and even then you will find very low numbers of many species, which makes it difficult to estimate a reliable mean value.

This table (*Fig.7*) shows a comparison of the Triple-D with the fine meshed 3 metre beam trawl, also for species larger than ½cm. We compared 8 hauls with the Triple-D with 8 hauls with the trawl. These are mean densities $n/1000m^2$ for a lot of different species and here in this column we see the ratio between the numbers caught in the Triple-D and the numbers caught in the trawl as $n/1000m^2$. As you can see many molluscs and bivalve species but also snails, are caught more than 100 times better in the Triple-D than in the 3 metre beam trawl. This is also the same for the two types of star fish and they were caught equally with both gears.

For crustacea the same is true. For many species the Triple-D estimates the density much higher than the trawl does, so the catch efficiency of Triple-D is also higher for crabs. It is remarkable that in the same species of crabs - males and females - the females are always buried in the sediment, it is part of their behaviour and as you can see the ratio shows that of the buried females, the Triple-D estimate of the mean density is much better than the trawl's estimate.

For fish the ratio is the other way round and as you can see fish is much better caught in fine mesh beam trawls than the Triple-D. I think it also depends on the small cutting blade and there is a great possibility to escape from both sides for fish.

Conclusion

In large scale monitoring programmes to detect temporal and spacial trends in bottom fauna and also in studies of the effect of trawling on bottom fauna, the best type of sampling gear has to depend on species, so box corers and grab samplers are suitable items to estimate the densities of small animals in a epifauna. When you want to sample the larger sized animals, however, you are better to use a Triple-D because this equipment is more suitable for low abundance infauna. When you want to know something about fish you use a traditional beam trawl. With regard to the last prototype I can assure you we are still improving it and the latest problem we had was that the counting wheel did not work very well on very soft bottom sediment.

Mr K G Robertson

Q You have Triple-D 94 and Triple-D 96, so what is going to happen in 1997 and I think you have already answered this but are there other changes that you would like to make?

Dr M Bergman

A I think we have a serious problem with the counting wheels, especially on soft bottom areas and we also have teething problems with the shape of the skis. We think in the front side the skis have to be much wider to give them more lift in a soft bottom area. This is also a point of discussion, but the wheels are the main point.

Mr K G Robertson

Q Can you tell me what protection you have for collision with a large piece of rock because this will always happen to somebody?

Dr M Bergman

A We have no protection. We only use it on soft bottom areas and we do a monitoring programme in the North Sea so that there are no stones at all. We are also doing studies of the effects of trawling, the effects of dumping harbour sludge and the effects of off-shore exploration of gas in the sea. In all these situations you have no rocks or boulders. It is certainly a problem and I think it is not designed to work with boulders, rocks or stones. I think we need a sort of snow plough but this would not be so good for the epifauna.

Mr K G Robertson

Q If the cable breaks, or something causes you to loose the Triple-D on the seabed, do you have any means of recovery; do you put an acoustic beacon on it?

Dr M Bergman

A We have lost it three times now; the line breaks but we have found it. We had sidescan sonar on the ship and we also dredged for it because the line laid straight ahead of the dredge. We also have a large buoy on it. Last time we got it back by searching for the buoy and fetching in a very thick line.

Mr K G Robertson

Q Most of time you are using this it is in shallow water?

Dr M Bergman

A We use it in depths of 15 metres but not much more.

Mr K G Robertson

Q It is always important to know the position where you are sampling, but in that depth you can probably rely on the position of the ship to tell you where you are?

Dr M Bergman

A Yes - we calculate the position of the antenna and we can make a good estimate.

Mr K G Robertson

Q When we are using box corers we find that the best results come from having people with a great deal of skill in using them. If we give it to somebody who has only seen a box corer just once before, very poor samples come back. The Triple-D seems to me that you could issue instructions and have people with less skill have success?

Dr M Bergman

A Perhaps. So far there are no problems. I think you almost need to be a detective to see what happens in reality because it is not that easy. The underside of the cage is controlled by a steering device and it is connected to the counting wheels, so when there are problems with the wheels - they are clogged or a piece of plastic gets into the wheel, or the wheels are slipping on soft bottom - then there are all kinds of problems. There are also problems in bringing the dredge after the preamble ends, to the right position and for instance, if next year you want to go to the same position, to make a comparison between a number of years and to follow temporal trends, then we think maybe there is a solution for this and then you have to steer the movement of the underside of the cage, the position and length of the hull from an onboard situation. You are on board, the dredge is connected to the ship and working with the DGPS of the ship, you push the button!

Mr K G Robertson

Q Are you planning different wheels?

Dr M Bergman

A We have just had a week in which we experienced difficulties but I do not yet have the reasons.

Mr K G Robertson

Q Can you give me some idea of the cost of the Triple-D. If somebody wanted to make one, or came to you and said will you make one for me?

Dr M Bergman

A I thinks the cost is about DG30,000 (which is about £10,000).

Mr K G Robertson

Q Is that about right - NIOZ?

NIOZ

A. I think that price is OK but for the time and all the peripherals around it, it has got to be more because it has taken us a long time at our Institute.

Mr K G Robertson

Q Ben Boorman, is this the sort of thing that you use in SOC, or is there discussion of using a device of this sort, because it is something a little bit new to me?

Mr B Boorman - SOC

A Generally, our work would be much deeper than this, so we could not use it for most of our work but if we had had it about 3 months ago it would have been very useful in the west of Shetland work. It would have been just what we needed.

Mr R Phipps - SOC

Q Compared with a box corer, what condition do the samples come up in? I imagine that after they have been dug up and washed to the back of a net, they look a bit ill? They come up perfect in a box corer.

Dr M Bergman

A They come up in a state depending on their weakness. Sea urchins are totally destroyed and only a fraction of the total numbers which are originally caught in the net are brought on board. Most of them are broken down in pieces but all other bivalves, snails, crabs, fish, are perfect.

Mr R Phipps

Q What sort of load does it put on the winch? Tonnage?

Dr M Bergman

A The towing in normal conditions is 1½ to 2 tonnes but can be higher.

Mr P Mason - RVS, SOC

Q You have done the development over a couple of years on different nets but is there any form of metering, either acoustic or electrical, so you know when it is level on the sea bottom ready to start sampling, when the cutting edge drops and when it comes back, or the distance moved along the seabed. Do you incorporate anything like that on it?

Dr M Bergman

A No. There is no electrical connection between the dredge and the ship now but we are discussing it. It would be much better and to have a video on it would be good, because you can see what it is doing but up until now we have no electrical things on it.

Mr P Mason

Q With a video you will need quite a high frequency cable. The other way would be to use acoustics for the basics, such as when it is on the bottom and distance moved along. Have you considered using acoustics?

Dr M Bergman

A In general, the technicians say there are problems with towed gears and acoustics.

Mr K G Robertson

Q One of the problem times with large pieces of heavy equipment is when they are going from the ship and going back on to the ship and the ship is moving. Do you rely on many people with many pieces of rope or do you have a special system, because I think we tend to rely too much on people and their strength when we should have special systems to guide these things?

Dr M Bergman

A We don't have special systems to guide the dredge going in and out but we worked on several ships and on the smaller ones they have only a small opening in the back of the ship, then we need people, one on each side to guide it but it is pulled on deck and then it stands on the hind side of the skis and is lowered flat so the side is up and there is no blade. On our own ship, which is much wider at the back, it comes on board without people guiding it.

Mr K G Robertson

Q On your ship do you have a ramp at the back?

Dr M Bergman

A No - nothing.

Mr J Dunn - Marine Laboratories Aberdeen

John Dunn had brought along a couple of videos, in case there was some interest in seeing them during the meeting. It is not practical to distribute multiple copies of the tapes but the verbatim record of John's additional remarks is given here for completeness.

The first video is called "Plankton Sampling" and it is one that came about because as I was developing equipment for various experiments and we were trying to answer particular problems. We came up with different types of equipment, so as a matter of practice, when we are at sea I like to try to photograph and video as much of the equipment as possible, so that when we come back to the laboratory, if there had been a problem, we could show the other technicians and guys in the workshop - "it is not right - it does this". I had all these pieces of video cluttering up my shelf and I decided I wanted them to all be put together and tell a story of what we had done and where we were going.

Then, of course, there was the problem of money, since no money was available for this. So I had to have it done 'in-house' by ourselves and somebody said you really need a narrator to tell the story, would you like to do it? I said no, so I met a guy on a aeroplane and it turned out that he was the guy who did the TV commentary for Tomorrow's World and I got talking to him about it and he seemed quite interested. I wrote out a script and sent it to him in London and he recorded it onto a cassette tape and sent to me for me to put it on to the video. He had 9 seconds of talking and I had 2 seconds of video and I had to elasticate, move and change things.

You will see on it is where we were looking at the problem of catching herring larvae and I know our friends from Holland and elsewhere have been involved in programmes where they have been trying to catch fish larvae and as was alluded to this morning, a lot of plankton become very aware of samplers and move out of the way. So you will see a progression of samplers that we tried.

The second video is a very specific programme where we had a mathematical model which had been developed to look at eutrophication in coastal waters or hypernitrification in coastal waters. It was decided to use a west coast sea loch as a giant tank of water, to experiment with this model but at the same time to fuel the model with good quality data, to calibrate all the instrumentation and specialist instrumentation that had been developed for it and to prove the model. As I have said to somebody already this morning, it is a bit like being the test pilot in a brand new aircraft when you are flying it for the first time and you casually step out of the cockpit, walk along the wing with a saw and saw off a piece of the wing, to see what affect it has on the plane! I don't recommend it but learning from my mistakes with the first video this time we were doing the science and we had a guy parked on the top of the container doing the video. The guy who did the narration for this one actually sat and watched the video and did the narration.

Mr R Phipps - RVS SOC
Q Did you have three station buoys with your instruments hanging from them?

Mr J Dunn
A Yes, we had three moorings - one in the mid-point of the outer loch, one at the middle of the intersection between the two upper and lower lochs and one up in the midpoint of the upper loch.

Mr R Phipps
Q You actually had buoys on the surface?

Mr J Dunn
A No, we had a marker buoy but the rest of the equipment was on a subsurface float, a big orange float.

Mr R Phipps
Q I have always wondered whether having something big like that your creatures are going to use it "to get out of the shade". Are you going to change their behaviour putting something like that in the sea?

Mr J Dunn

A The main problem in that area is that we needed to go back to the same positions and the guard buoy ended up being the buoy that we actually moored the research vessel up to, to give us peace to deal with the instrumentation that were going up on the stern. The other problem we had was initially something that we hadn't contemplated, the depth of the water was almost 3,000 metres. We had been used to doing North Sea moorings in 200 metres, so we needed a completely new kit.

Mr R Phipps
Q You don't think this equipment unduly affected their behaviour?

Mr J Dunn
A It did not seem to have any effect whatsoever.

Mr K G Robertson
Q You showed a lot of different instrumentation; some specialised and some not quite so specialised but all rather unusual in general terms. Do you find you have to develop much of your own instrumentation because of its unique nature, or is there a lot that you can buy from existing companies.

Mr J Dunn
A In our department, if we can buy it from a company and it will do what we need it to do, we don't make it. The problem being that we are always pushing to have something more accurate with more parameters and it is either a case of buy somebody's and modify it or make it yourself, so if we have the facilities to make it ourselves and it is going to be cost effective to do it, we do it.

For one problem we have had, you may have seen the nutrient device for monitoring the nitrate and most of you will see it in your WS Oceans pack. This is now commercially available as the AS monitoring systems but you won't see any reference to the fact that we invented it. We sold it to WS Ocean Systems in good faith and we have disappeared off the map and it was us that cracked it in the first place and it was test driven over that entire year. It is worth noting of those particular instruments, we did not have a single failure in any of them. We had two failures in battery packs but for the actual nitrate analysers themselves, not one single failure over an entire year which for a brand new kit, we thought was pretty good.

Mr K G Robertson
Q You were using the "Challenger", which I am very pleased to see. You were also using other ships. Do you design your experiments and design your instruments, so that they can be flexible and used for a range of ships. Is this a necessary function?

Mr J Dunn
A This has become more of a function. We used to have the luxury of having about five research vessels in our own fleet but at present we have two, one small sized one and one about the "Challenger" size; the "Scotia", which is now being replaced. However, we have to use ships of opportunity so going back to something that was said this morning, do you need special cables and things. We have to make our instrumentation "stand-alone", so that it can be used from a ship that happens to have a wire cable. On some of the ships, for example the one that was shown, was actually an oil rig supply vessel so we had to put on an A frame, we had to put on winches. We borrowed a container laboratory from NIOZ because there were no laboratories. We tried to borrow one from NERC but they did not have any available. We have had to become very self-sufficient in turning around a vessel that will come in at a price we can afford to do our job.

K G Robertson - Comment
If you ever need container labs you can contact Mr George Batten - you can come to RVS. It was said in the second video that a regular sampling programme is necessary, with repeated trips to sea with a team of people. That is an expensive process to keep mobilising a ship and people and keep taking them to sea, are you working on the idea of longer term measurements perhaps with benthic laboratories, or perhaps with other means?

Mr J Dunn

A Yes - that is the next big hurdle. It has been talked about several times this week and this is to set up equipment that will sit on the bottom and measure various parameters, self-calibrate or check-calibrate and either store this information locally or send that information back by satellite. Similarly, with other long term buoy deployments because I don't think we can sustain sending the number of people we would like to send to sea to carry out our programme. I think that way after the Loch Linnie programme. We had a team of 8 people and it was the same 8 people who were on the ship, doing the job, back ashore analysing the results, preparing the equipment, loading the equipment, unloading the equipment, etc. it is a killer and I wouldn't do it again. I like to keep to my job and not be involved in everybody else's.

Mr K G Robertson

Q This is obviously a common problem. A lot of instrumentation was used and some of it you encourage industry to take up and produce. Is all the detail of these items published somewhere? Could we get hold of information from somewhere if someone saw something today that was interesting?

Mr J Dunn

A Yes - it is all published. ARIES was published in Deep Sea Research and if anyone wishes to contact me I will certainly furnish them with the papers. LOCHNESS - there are several papers all published again both on the apparatus itself and the sampling and the avoidance of various animals from LOCHNESS, and if anybody is interested for teaching purposes or reference, copies of the video are available if they contact me I can supply you with these.

Mr K G Robertson

That is very generous - I am sure people will take notice of that.

Mr Paul Ridout

Q I was lucky enough to be involved in the bag experiments in Loch Ewe during the 1980s, did the Loch Linnie project use any of the data or information from this for design?

Mr J Dunn

A Sort of! We used some of the information we had gained and some of the processes we had ironed out in the bag experiments but other than that it was scaling it up. We did it in small scale in the bag and now we were actually using this huge Loch as an enormous tank of water, instead of having it in a huge plastic bag.

Mr K G Robertson

Q In the first video you mentioned a 'roof-rack' sampler. Is that solely because of the shape of the thing or some other reason?

Mr J Dunn

A The deck crew like to give things names and they nicknamed this "roof-rack" because it looks like a roofrack. The idea was that it could be quickly and easily disconnected and taken it in the laboratory if you wish to alter the configuration of the instrumentation, or if you have a problem. Rather than work on it out on deck, you could take it inside and work on it and open up the electronic packages quickly and easily. We also used to have two roof-racks so if one screwed up, you just hooked one off and put the other one on and there was no downtime.

Mr K G Robertson

Q With all that range of instrumentation at your disposal it would be easy to say 'you've got it all' there is nothing more you need, but I am sure that is not true. What instrument development projects are either still under way with you or being considered, or in fact might be needed in the future?

Mr J Dunn

A We have a project at the moment we are involved in call the "TransAtlantic Study of Calanus?" where we have developed a much stronger and tougher version of Aries which can be launched up and down a ramp of a stern trawler and in about November/December 96 we are going to put it down to about 6000 metres, between the North end of Faroe and the South end of Iceland. You may have seen in the videos that we have used on a regular basis the commercially available Scanmar system which we use to determine where the sampler is in the water colum. Scanmar, unfortunately, despite pushing them, will not come up with something that is going to go to 6000 metres, so we are now looking to reverting back to the IOS system which we used on LOCHNESS and elsewhere to actually determine where the sampler is in the water column but if anybody has got a better system or something which will operate at the range we are looking at, I would be delighted to hear from them.

Mr K G Robertson
I see Ben Boorman looking - reverting to the IOS system!!! Have you anything to say about that Ben? Particularly in deep water because you have experience in those areas, but then I think you are going to have to think about navigation, etc.

Mr B Boorman IOS SOC
A Talk to our technology department about it - I know nothing about acoustics.

Mr K G Robertson
Q What about deep water? You have a lot of experience there? Any particular things that you have to be wary about perhaps?

Mr B Boorman
A Talk to the technology people.

Mr K G Robertson
Q What about navigation? I have mentioned it because it is something that does concern us with deep tow instruments and when you go to 6,000 metres, that is deep and quite a long way behind the ship somewhere and do you know the attitude and the angle, have you thought about where it is you are taking your samples, because this is something that we know what to do about it, but the solutions are generally quite expensive?

Mr J Dunn
A The solutions are tremendously expensive and we are working on that at the moment, trying several methods. We know that the system flies straight and level and that is the best we have come up with yet. As to where it might be on that length of wire, either to port or starboard at this point in time, we have not cracked that.

Mr K G Robertson
Q Again to use Ben's words, talk to the Technology Department in SOC because we are beginning to get experience in some of these systems and it might be useful to help you avoid some of the obvious snags that can occur and the pitfalls.

Mrs K Bouton, OCEANIC, Delaware, USA

"The Internet and the World Wide Web"

Katherine used a PC with an attached projector to demonstrate her talk. The data from the Internet had been loaded to a CD-Rom for speed and convenience. The verbatim commentary is recorded here as a reminder and for further information.

I come from the University of Delaware, College of Marine Studies where we have set up a system called OCEANIC, the Ocean Network Information System. Originally we were set up to be WOCE (World Oceans Experiment Information Unit) and when we started doing that we realised that a lot of the planning for WOCE required ship scheduling and so we wanted to organise an on-line ship scheduling data base, so researchers for WOCE could look and compile resources and say ‘a ship is going off to the Pacific - I can maybe put my equipment on there’ and when we started putting these ship schedules on line, we found out there was a greater need than WOCE for a lot of planning and organisation for countries worldwide, so we have been asked to put on-line ship schedules and characteristics.

When I was invited to this meeting they did not give any exact subject they just suggested Internet and the World Wide Web (WWW), so what I did was I went and explored the Web, pretending I was a technician. I know they're involved with Standards and Calibrations, Fishing Technology, Mooring Technology, etc., so I thought what would be of interest to them.

The Internet is basically a huge compilation of information that it available on computer wires. There is so much information it is overwhelming but the pieces that are out there and that you can find and how you can find them and start to explore, can provide useful information. Also you as technicians can provide this information for other people to go out and find.

One of the things you can find out are ship manuals. I don’t know how often you have to update your ship manuals and deck plans, etc., but this is one of the questions most people get asked - "what is the layout of your ship, where can I put my equipment, what do the cabins look like, what do the electrical rooms look like?" etc., so I have gone and found a couple of examples of what I think are very useful ship manuals that are currently available on the Internet. One of them is the “WECOMA” and they have done a very good job of putting up their ship manual.

The WWW is a distributed information system that can be looked at by a Web Browser and one of the Web browsers that I am using is a piece of free software to educational institutes called "Netscape". All the links that are blue you just click on and they take you anywhere in the world. They can take you to the same PC you are looking at or they can take you to Australia or anywhere in the world.

This is the “WECOMA” homepage - and then they have allowed the user to come in and look at the ship’s equipment and capabilities, common use equipment, cruise preparation information, things like paperwork a scientist would need to fill out before the cruise, scheduling information, ship board computing; so I could find out as a scientist what type of computers would be available. They give general information and what they are trying to do is put all their resources in our place on their Web site. It gives the characteristics of what the ship looks like, how many feet of electronic labs they have, etc. I keep in mind that the blue links into further details. I’m a scientist and I want to check the dry lab. Here is information on the dry lab, it tells me how big it is, what kind of access I have, what kind of electricity, etc. Then, more importantly, what it looks like, where the wet labs are and where the dry labs are. I have seen more detailed manuals which show you where the electrical points are in the lab, where the container layouts are going to be and what sort of electrical plugs you need.

Other things that you can do - “Discovery” one of our host ships has done a really good job of putting its movements from its MET observations and puts up little reports about where they are and where they can be found. This is useful not only for the scientists but also to get data. This is a map of the “Discovery”s position data and lets the user signing on the Web site find out where the ship is. You can do this from your home site if you want to track where ships are going and provide that information to the users.

If you are looking for information on instrumentation and manufacturer’s specifications, you can get that from the Internet. SeaSoar has a Web site and they provide a very nice piece of information on their SeaSoar equipment. This gives details on the equipment, who is using them and how they can be used, specifications and basically it provides very high level manual information. This would give you a starting place where you could get information. This is not just for the SeaSoar, a lot of equipment companies are getting this type of manual information on line for you to use.

Lost instruments have been discussed a lot. Moorings lost and how do we find out where they are. There is an office in Woods Hole called the "Lost Equipment Network" and they are beginning to get quite well noticed. It is basically a Bulletin Board where you can post information on where you lost your instruments and where you found instruments and sometimes they do have success stories matching the two, lost to found.

For example, in the case of Found Instruments like transducers, buoys and so on. They are on the Web with a simple e-mail message that says where you have found it, what it is and who to contact. Lost Instruments includes a seismometer and a good description showing where it was last seen and who to contact. You simply subscribe to an electronic mailing list and when you send an e-mail address to this it goes out to everybody on that mailing list and on to the Bulletin Board, so if you are interested in finding lost equipment, it would be a good idea to start subscribing to this Bulletin Board.

Presuming that you have e-mail, you can start e-mail lists on your own, or have groups, or you can set up e-mail lists that are subject orientated, or perhaps that are specifically ship orientated. You could have an e-mail list for a cruise so that everyone on the cruise would get the same messages about cruise dates and plans, etc. There are zillions of lists out there, on all sorts of subjects. There is a list called "Marine-L" which is an open forum on marine related topics. There is "Marine Facilities" for those who are involved in marine research facilities and there is actually a "Marine Technology" list sponsored out of the UK.

OCEANIC is trying to be a central hub of information for all this distributed information. It is so big that it is very hard to find what you want, so popping up all over are organisations like ourselves which act as a centralised source which points you to other places of information. There are also searching capabilities - something that is called “YAHOO” which you can sign on to. It is a searching mechanism where you can look under Science, Oceanography, Marine Technology and it would then send you to all the places that are involved with marine technology.

OCEANIC has our ship schedules on line which are searchable for scientists who want to look for cruises that are going to the Pacific in, say January 1997. He can then search and find which ships are in the Pacific during that time and then get in contact and see whether there is space available to put on different types of equipment, etc. It is also good for the operations side because if they have schedules with open time available, someone can search and find out who has open space that they can use. We have information listed by country and also information from all over the world. The hardest part is getting the information into the system and it is people like the marine technicians that if you could send OCEANIC your updated schedules and your cruise plans, we could put them on line for you if you are not going to do this yourself.

Mr K G Robertson

Q Mr Robert Lloyd is responsible within for the Web Pages that Research Vessel Services (RVS) generate through SOC. Robert has been involved with this since the first time we actually wondered if it was a good idea and ‘yes - lets go’. Robert is our Webmaster and if you look on the RVS pages, at the bottom if you click on that and you get a picture of Robert in Antarctic protective clothing.

Katherine has mentioned that setting up your own pages and generating text is so easy it is unbelievable. Robert, would you care to comment as somebody who started from scratch, but with the right background of the technology?

Mr R Lloyd - RVS

A Certainly we have found it very easy to set up Web pages. We do less of advertising ourselves but more of providing a service to people who are using our ships. We routinely put up ship positions and just a brief summary of what the ship has done that week or over the last few days and one of the things I would like to bring out from Katherine's talk it that the resources out there on the Web give you a very powerful tool, creating a service to others. You saw "Discovery"s position about a month or so ago. That position is being updated twice a day. The way we do it is to read another Web site. We interpret the data on that other Web site and we then format it to create a link to the Xerox Map Server, so here we are in Southampton but you access the ocean weather site in the US. We have extracted some data that our own ship placed on that site and then we formatted it with a call to the Xerox Map Service. That is the power of the Web which makes things quite exciting and easy to use. The Xerox Centre is in California.

Mrs K Bouton

A There are skills other than word processing involved. There is programming that is needed to do that type of thing. You can actually connect to relational data bases which is something to get your basic pages up and that is relatively easy. It can provide incredible amounts of information to your users.

Mr R Lloyd

A One of the conventions within the Web is that if you know there is useful information out there you will often provide pointers to other sites. For instance, OCEANIC point to RVS, RVS point back to OCEANIC, RVS point towards the NATO Centre, to OIR in Japan and to a number of other sites. In that way relatively new people to the Web don't have to go very far before they can go a very long way! You don't have to know wholly what is out there and you will be guided by others who already have that experience.

Mrs K Bouton

When you start creating your own page there are several things to keep in mind. It is really easy on the Web to get very flashy with lots of pictures, icons and logos but what you have to keep in mind is that people are coming to you from all around the world and the further away they are the longer it takes for that connection to come across the ocean basins. Keep your images to a minimum. Rather than having pictures, create links so the user can choose to look at that picture rather than being forced to have all these images loaded forced on him. At the bottom of each page make sure that there is a date when the page was last updated and a contact name. Keep it simple, keep it informative, think of your user and what it is your user wants to see.

Mrs K Bouton

Let me give you some idea of how to start and my example will be OCEANIC. When you're in the Web browser "Netscape" all you have to do is type in **www.cms.udel.edu** and that will take you to our home page. There are two search engines that I use all time, you use them for different reasons. YAHOO is called hierarchical, in that you can go in by subject and you can work your way down very carefully to a hierarchial tree and the address for that is **www.yahoo.com** and that is an excellent resource. The other way to search is more by keyword so if you haven't got a clue of what subject it might be in the card catalogue, you do know that it is a specific instrument, for instance, SeaSoar, by keyword. There is also a search engine called "ALTA VISTA" and that is located at **www.altavista.digital.com.** This will present you with a bar that you type your keyword in and it will search 100,000s of Web sites, related to that keyword until it presents you with places where you might go for that keyword search.

Mr K G Robertson

Q It seems to me that these search engines are more and more essential because there is so much information and the key words are necessary. Lets not go overboard too quickly on this for those who might be new to it because there are protocols and there are security considerations to take into account. Where would people like yourself suggest that somebody who is very new to the Web and wants to start and does not know how to, where would you suggest they begin because there is a lot of information out there on the Web itself on how to do it?

Mrs K Bouton

A Five years ago I could not find a book on how to write '**html**' or what the Web was about and I went in the bookstore and there were rows and rows and rows of books, so I just picked the fattest one. I learned '**Perl**' a computing language in 21 days. If you just go to the bookstore there are so many books now and they all cover the basics and I couldn't recommend a particular one but look through and find one which reads the best for yourself. On the Web there are also Web tutorials which you can find going through YAHOO under www.documentation and this will walk you through step by step on how to use it.

Mr E B Cooper - ISG SOC

Q I enthuse about the Web and if you want examples of what is really good on the Web go to the NASA pages. They have got a mandate to tell the general public what they do in the States and to make sure people know what they are doing with the tax dollar. They have some tremendous demonstrations on the Web but having said that the Web is great in its resource but you have to be careful that everything on it is correct. Don't book your holidays based solely on the cruise programmes shown on the Web. Also if you are a technician or a manager just be aware that the Web is addictive. The first couple of days that someone has access to the Web they will do little else other than ping around all the different sites. After about 2 days they get bored with it and then they go back to doing the work that they had. Make use of it but be sensible in making use of it.

Dr K Bouton

A That is part of its nature, you can go from link to link to link very easily.

Mr E B Cooper

From my experience in using the Web a fair amount, I find I never end up with what I really set out to get. I found out all these other things but I run out of time of find out about the original thing I went on there for.

Mr P Ridout - Ocean Scientific

Q I would like to endorse that last statement. There was an article in "The Times" today that says that an average small company with fifty employees estimate they are wasting £100,000 per year now on people Web browsing. It is something that genuinely worries me in terms of it is a resource that has a lot of hype and has a lot of excitement about it but we are a small company with a budget that is tightly controlled and we have to be very careful if, or how, we use a facility like this. At the moment we have shied away from using it. We have one page within the WOCE pages at SOC to give out information about standards because we manufacture calibration standards but from that point onwards, especially as my feeble attempts to explore the Web have panicked me into going back to my E-mail and telephone to do real business, it has disillusioned me a little bit.

OCEANIC is used to putting out new information. If we brought out a new standard which has a commercial angle but it has a scientific value also, we used to put that information out on OMNET and that used to hit everybody at once. The response was good and OMNET was accepted as a slightly halfway house between academic and commercial. Is this something we could do with OCEANIC?

Dr K Bouton

A With the demise of OMNET went a lot of things and one of them was this type of access to the oceanographic community as well as the OMNET bulletin boards, etc. I know that OMNET is trying to come back with an Internet address, however they are charging and I don't know if they will get a lot of takers for that. Currently we only put non-commercial and university information up but there is nothing to stop you from compiling your own e-mail mailing list which you could send out to people you know would be interested. We are thinking about putting bulletin boards up because this is something that is sorely missing in the community but unfortunately just to put it up doesn't do anything, people have to come and look at and there has to be active involvement in it.

Mr P Ridout

Q We are certainly starting to get enquiries which originate from the Internet and from some Internet groups. We got one from the US Navy the other day about salinity measurement and we are responding to that but I feel that with our page somewhere in the depths of the WOCE pages, people would have to work hard to find it and it is the initial access points that I find difficult too. As Ed Cooper was saying, you don't end up finding what you originally went out to look for and that can be very frustrating at times.

Dr K Bouton

A There is a lot involved in designing systems in which you can find the information easily. I just want to make a point about wasting resources with people fiddling around with their computers. I think it is an interesting point but as was said earlier, people tend to get bored with it after a while but also originally when the telephone came around I remember people would spend hours and hours on the telephone setting up office policies and you have to make a policy that they don't use the phone for anything other than business calls. You can try to make policies like that around the office.

Mr E Cooper

I would just like to expand on Robert Lloyd's work in getting the ships' positions plotted on the Xerox chart based on the met (meteorological) observations. In a practical sense we know that information is used by technicians' families, the wife of the Bosun, the wife of the Chief Engineer, to see where the ship is and it gives them some sort of confidence. They may not be communicating with the ship but they get an involvement in what is happening.

In terms of work, that very image that was up there was probably used by somebody at Plymouth to decide which part of a satellite image to send to the ship. It is no good sending the ship a satellite image if the ship is not within the area that the image is of and we know that a colleague of ours down in Plymouth refers to the Web and the daily chart in order to determine where the ship is, in order to determine which part of the satellite image is going to be of interest to the ship, rather than waiting for the people on the ship to remember to tell him that he is trying to monitor where they are going in 6 weeks, and they are making decisions on the fly as to what they do each 12 hours and they may have decided not to go to 50^{o} North because maybe the weather was lousy, but no one has conveyed that piece of information to him. So, therefore, he is looking at the Met Ops which are put back by the Radio Officer on the NERC Research Ships. Every 6 hours he sends off the Met Ops to Bracknell and Bracknell include it on the met database and that is what we are accessing. We did try to ask the ships' Masters to format messages in the correct format so that they could go straight on to our system but that generally failed so now we have tagged on to an official route that they comply with.

Mr K G Robertson

Q Katherine **-** Am I right to assume that you would welcome as much information as anyone is prepared to give to you, even if it is just the details of a link to their site, no matter what is on that site.

Dr K Bouton

A Absolutely. The exact opposite is true too, we would be happy to answer any questions you might have. Please use me as a resource on how to write Web pages. You could send me a document and I can give you an example of what it would look like when you put something like that up on the Web. OCEANIC is also willing and able to help if you don't have space available where you might want to put up a manual. That is something we could discuss with you and have it put on the Web for you. If you don't have a computer at your home site of your Institution, that is something we would be able to provide as part of our ISOM function.

Mr R Phipps

Q I am completely ignorant of this system, although I have known of its existence for a while. It seems obvious to me that information about everybody's ships should be on there including deck plans, lab space, etc., so anybody can just go to it. So if somebody wanted to do a bit of science in the Indian Ocean or whatever, just go to the Web and see **-** 'yes they have enough space' **-** I'll get in touch with them. Do we do that? Can you find out information about ships?

Dr K Bouton

A OCEANIC maintain the schedules and the ship characteristics for NERC ships.

Mr E B Cooper

A There aren't the details down to the level we saw for WECOMA, like the layout of the labs, etc., but there is an open invitation to the Engineering Group with RVS Scientific to provide that information and put it on to the Web. I am trying to get some management initiative into promoting RVS Scientific and our facilities through the Web. The intention is that each of the groups put these sort of details on to the Web. We have the scanners and we've got Robert Lloyd who knows the technology and language but we can't ask Robert to do it all, we need to give him the information.

There are things like the RVS Mission Statement on the Web and we invite our customers to come and read it.

Dr K Bouton

When you start to think about putting things on the Web it seems overwhelming and the resources can be too much but when you think about what you save in the long run, instead of having to Xerox and mail manuals or spend hours on the telephone trying to describe what something looks like, you just point them to a Web site - manuals, deck layouts - all there! It pays off in the long run.

Mr S Worrilow

Q Most of the times I am working on a ship it is because I have something on the surface unexpectedly and I need some way easy that I can say "I need to be in the North Western Atlantic as soon as possible" - "What is available?" This year I have used quite a few of the Canadian Coast Guard vessels. I know most of these vessels are doing weather operations so is there some way I can automatically pick off ships from the Weather Service and get position of ships in a specific area?

Mr R Lloyd

A The site I use to download our ship positions is called "**oceanweather.com**". This is really a very good site with ordinary text information but also maps and they do map the ocean basins. It is not particularly user-friendly because it relies on you knowing the international call sign of the ships concerned but it gives a list of buoy positions, fixed platforms and ships and their current position and current weather. So if there is a position which is close to any of your drifters, you shouldn't have too much trouble decoding the international call sign of the ship concerned and contacting the ship operator. Katherine do you have a list of international call signs?

Dr K Bouton

A OCEANIC points to the IGOSS international call-sign list which is more or less up-to-date.

Mr R Lloyd

So yes, Scott, it can be done. As I said, **oceanweather.com** is a good site with some good graphics based on the ocean basins and they use the international call-sign as opposed to ship names.

Dr K Bouton

Is there a charge for this or do you need to be a registered user for this?

Mr R Lloyd

A No - this is a public service.

Dr K Bouton

Don't give your credit card number out over the Web. If you see something you want to order, get the telephone number and call them. It is not that secure just yet.

Mr K G Robertson

That is a good point and some pages do issue a warning before you proceed too much further about the security of information, security of passwords, the security of credit cards, etc. Be very careful is the answer, because there is a whole thing about selling products over the Web and it seems to be very easy but the security level is really quite low.

Dr K Bouton

It depends on each Institution on how low the security is but you can set security at different levels wherever you are. You can set up your own Web site password protected files and things that only those users you want to can have access. However, anything that is wired together has access by somebody, so if you really don't want somebody to read it, don't put it on the network.

Mr K G Robertson

Final conclusions and farewell

We have a coach arriving at the door shortly and we will do what we can to show you some of SOC. Some of it is true University with Teaching Labs and students, etc. We will show you just a part of it. As we go round the site, please speak up and say if there is anything in particular you would like to see and we will tell you whether it is possible or not. Some people do want to speak to Ian Waddington, who will be there to talk about mooring components, etc.

We started on Monday saying this was the first Workshop and I hope it is not the last. I think it has been good and been great to bring people together to meet new people and to get to know a little about each others' organisation and each others' problems, which was what it was really all about. A limited range of three main subjects was chosen but I think we would have been hard pushed to deal with any more. In fact, I think we could have taken any one of those and expanded the whole thing. Thank you to everybody for coming along and to those who are absent on this last day, please pass on the same set of thanks. Thank you to all our speakers. It is a harrowing job getting up and speaking, especially if English isn't your native language and we appreciate it very much indeed.

As I said at the beginning, part of the condition from the European Commission was that a synopsis report is produced and that has to be done within two months. It is quite a job, especially when I saw last night that our friend at the back recording these proceedings was on Tape 8 and there are probably more by now, it is a lot of material to get through. You will get a copy of all this and a copy of all the information that is available, lists of people, where they come from, their e-mail addresses and so on.

Thank you very much - nice to have met you all - let's have a tour around SOC - hope to see you again in the US next time - maybe there will also be a call for volunteers for other people to host it - goodbye and thank you.

§

Thanks and acknowledgements

This report has been composed from transcriptions of audio recordings made during the Workshop and from presentation material provided by the invited speakers. I would like to extend again my thanks to all those who took part in the proceedings and in particular, the speakers, without whom the event could not have succeeded.

A special vote of thanks and appreciation must go to Mrs. Carol Macgonigal, who took on the daunting job of transcribing the entire three days worth of audio tapes into the many pages of word processor text that comprises this report. My job was made so much easier as a result.

K.G.Robertson
Workshop Chairman
Scientific Superintendent RVS
September 1997

APPENDIX

LIST OF ATTENDEES
&
CONTACT DETAILS

NAME	INSTITUTION	ADDRESS	TELEPHONE/FAX/E-MAIL
Addison, S Technician in Ocean Laboratory	University of Aberdeen	Tillydrone Avenue, Aberdeen, AB9 2TN Scotland	Phone: +44 (0) 1224 272889 Fax: + 44 (0) 1224 272889 E-Mail: s.addison@abdn.ac.uk
Ashley, J Electronic Engineer	Proudman Oceanographic Laboratories	Bidston Observatory, Bidston Merseyside L43 7RA	Phone: (0) 151 653 8633 Fax: (0) 151 653 6269 E-Mail: joa@pol.ac.uk
Atsuo, I Chief of Dept of Marine Science & Technology	Nippon Marine Enterprises Ltd	14-1 Ogawa-Cho, Yokosuka, 238, Japan	Phone: +81 468 24 4611 Fax: +81 468 24 6577 E-Mail: itoa@jamstec.go.jp
Ayres, D	Isothermal Technology Ltd	Pine Grove, Southport Merseyside, PR9 9AG	Phone: +44 (0) 1704 543830 Fax: +44 (0) 1704 544799

Backers, J Project Engineer	Ministry of Environment (M.U.M.M.)	Liniregiments Plein, 8400 Oostende, Belgium	Phone: +32 59 70 01 31 Fax: +32 59 704935 E-Mail: bmmost@camme.ac.be
Bakker, K Chemical Engineer	NIOZ, Netherlands Institute for Sea Research	PO Box 59, 1790 AB Den Burg, Texel, The Netherlands	Phone: +31 222 369450 Fax: +31 222 319674 E-Mail: karelb@nioz.nl
Batten, G M Head of Scientific Engineering Group	NERC, Research Vessel Services	Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH	Phone: +44 (0) 1703 596049 Fax: +44 (0) 1703 596066 E-Mail: george.batten@soc.soton.ac.uk
Bergman, M	NIOZ, Netherlands Institute for Sea Research	PO Box 59, 1790 AB Den Burg, Texel, The Netherlands	Phone: +31 (0) 222 369474 Fax: +31 (0) 222 319674 E-Mail: magda@nioz.nl

Boorman, B	George Deacon Division	Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH	Phone: +44 (0) 1703 596356 Fax: +44 (0) 1703 596247 E-Mail: ben@soc.soton.ac.uk
Bos, E Technician	NIOZ, Netherlands Institute for Sea Research	PO Box 59, 1790 AB Den Burg, Texel, The Netherlands	Phone: +31 (0) 222 369300 Fax: +31 (0) 222 319674 E-Mail: eduard@nioz.nl
Bouton, K	College of Marine Studies, University of Delaware	Lewes, DE 19958, USA	Phone: (302) 645 4278 Fax: (302) 645 4007 E-Mail: bouton@udel.edu
Bradley, S Architect for Deep Ocean Systems	Dept of Engineering University of Aberdeen	Fraser Noble Building, Old Aberdeen, Scotland	Phone: +44 (0) 1224 272889 Fax: +44 (0) 1224 272396 E-Mail: s.bradley@abdn.ac.uk

Bremner, S Mechanical Design Engineer	British Antarctic Survey	High Cross, Madingley Road, Cambridge, CB3 0ET	Phone: +44 (0) 1223 251400 Fax: +44 (0) 1223 362616 E-Mail: sfbr@pcmail.nerc-bas.ac.uk
Brummer, G J	NIOZ, Netherlands Institute for Sea Research	PO Box 59, 1790 AB Den Burg. Texel, The Netherlands	Phone: +31 (0) 222 369442 Fax: +31 (0) 222 319674 E-Mail: brummer@nioz.nl
Bryden, H	James Rennell Division for Ocean Circulation	Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH	Phone +44 (0) 1703 59 6437 Fax: +44 (0) 1703 596204 E-Mail: hlw@soc.soton.ac.uk
Christodoulou, C Physicist	Institute of Marine Biology (IMBC)	PO Box 2214, Heraklion Port, Heraklion, Crete.	Phone: +3081 243022/241992 Fax: +3081 241882 E-Mail: Kchris@imbc.gr

Cisneros Aguirre, J PhD Student	University of Las Palmas Grupo de Oceanografia Fisica	Apdo 550, 35017 Las Palmas, Grand Canaria	Phone: +(9) 28 451289 Fax: +(9) 26 452 922 E-Mail: Cisneros@ciemar4.ulpgc.es
Cooper, E Head of Information Systems Group	NERC,Research Vessel Services	Southampton Oceanography Centre, Empress Dock, Southampton SO!4 3ZH	Phone: +44 (0) 1703 596389 Fax: +44 (0) 1703 59`6383 E-Mail: edward.cooper@soc.soton.ac.uk
De Blauwe, J P	M.U.M.M. Ministry of Environment	Liniregiments Plein, 8400 Oostende, Belgium	Phone: +32 59 70 07 31 Fax: +32 59 70 49 35 E-Mail: bmmost@camme.ac.be
Derksen, J Software Engineer	NIOZ, Netherlands Institute for Sea Research	PO Box 59, 1790 AB Den Burg, Texel, The Netherlands	Phone: +31 (0) 222 369328 Fax: +31 ((0) 222 319674 E-Mail: jand@nioz.nl

Diaz, G C Technician	Instuto Ciencias del Mar	Paseo Juan de Borbon, S/N 08039 Barcelona, SPAIN	Phone: +34 (3) 221 64 16 Fax: +34 (3) 221 73 40
Dieter, E R Programme Manager Ship Operations	National Science Foundation	Division of Ocean Sciences, 4201 Wilson Blud, Arlington, VA 22230, USA	Phone: 001 703 306 1577 Fax: 001 703 306 0390 E-Mail: edieter@nsf.goo
Dunn, J Higher Scientific Officer	S.O.A.F.E.D. Marine Lab	PO Box 101, Victoria Road, Torry, Aberdeen AB9 8DB	Phone: (0) 1224 295311 Fax: (0) 1224 295511 E-Mail: DunnJ@marlab.ac.uk
Fogg, B	M.A.F.F.	Fisheries Laboratory, Pakefield Road, Lowestoft, Suffolk	Phone: +44 (0) 1502 524310 Fax: +44 (0) 1502 524318 E-Mail: b.fogg@dff.maff.gov.uk

Groenewegen, R Head of Electronics	NIOZ, Netherlands Institute for Sea Research	PO Box 59, 1790 AB Den Burg, Texel, The Netherlands	Phone: +31 (0) 222 369333 Fax: +31 (0) 222 319674 E-Mail: ruudg@nioz.nl
Hanyu, M	Global Ocean Development Inc	3-65 Oppamahigash:- CHO, Yokosuka, 237 Japan	Phone: +81 468 24 4611 Fax: +81 468 24 6577 E-Mail: hanyum@jamstec.go.jp
Hartling, A J Programmer of Planning Physical Oceanography	Bedford Institute of Oceanography	PO Box 1006, Dartmouth, Nova Scotia, Canada, BZY 4AZ	Phone: 902 426 6102 Fax: 902 426 7827 E-Mail: hartling@binet.bio.dfo.ca

Heiden, D Sales Manager for Special Cables & Braids	Cousin Trestec	8 Rue Abbe Bonpain, 59117, Wervicq-Sud, FRANCE	Phone: 00 33 139 728 770 Fax: 00 33 139 728 771
Hiehle, M A Data Analyst	NIOZ, Netherlands Institute for Sea Research	PO Box 59, 1790 AB Den Burg, Texel, The Netherlands	Phone: +31 (0) 222 369429 Fax: + 31 (0) 222 319674 E-Mail: hiehle@nioz.nl
Horton, B Head of Nets & Gear	M.A.F.F. Directorate of Fisheries Research	Main Laboratory, Pakefield Road, Lowestoft, Suffolk, NR33 0HT	Phone: (0) 1502 562244 Fax: (0) 1502 5254318 E-Mail: b.g.horton@dfr.maff.gov.uk

Howarth, P Instrumentation Technician	Research Vessel Services	Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH	Phone: +44 (0) 1703 596220 Fax: +44 (0) 1703 596279 E-Mail: phow@soc.soton.ac.uk
Hudson, P Technician	M.A.F.F.	Fisheries Laboratory, Pakefield Road, Lowestoft, Suffolk	Phone: +44 (0) 1502 524310 Fax: +44 (0) 1502 524318 E-Mail: p.hudson@dff.maff.gov.uk
Jolly, D Instrumentation Technician	Research Vessel Services	Southampton Oceanography Centre, Empress Dock, Southampton, SO14 3ZH	Phone: +44 (0) 1703 596220 Fax: +44 (0) 1703 596279 E-Mail: djj1@soc.soton.ac.uk

Jones, A Instrumentati on Technician	NERC, Research Vessel Services	Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH	Phone: +44 (0) 1703 596219 Fax: +44 (0) 1703 696279 E-Mail: akj@soc.soton.ac.uk
Kramer, J M Senior Scientist & Consultant	Mermayde	PO Box 109, 1860 AC Bergen, The Netherlands	Phone/Fax: +31 72 5818182 E-Mail: mermayde@xs4all.nl
Larson, N G Vice President for Science	Sea-Bird Electronics, Inc	1808 136th Place NE, Bellevue, WA 98005-2398 USA	Phone: (206) 643-9866 Fax: (206 643-9954 Internet: norge@seabird.com

Lloyd, R Scientific Information Group	NERC, Research Vessel Services	Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH	Phone: +44 (0) 1703 596388 Fax: +44 (0) 1703 596383 E-Mail: rbl@soc.soton.ac.uk
Lowry, R	Proudman Oceanographic Laboratory	Bidston, Birkenhead, Merseyside, L43 7RA	Phone: +44 (0) 151 653 8633 Fax: +44 (o) 151 653 6269
Manriquez, M Vice Head Scientific Maintenance	Instuto de Ciencias del Mar	Paseo Juan de Bordon, S/N, 08039 Barcelona, SPAIN	Phone: +34 (3) 221 64 16 Fax: +34 (3) 221 73 40 E-Mail: mar@icm.csic.es

Mason, P Scientific Engineering Group	NERC,Research Vessel Services	Southampton Oceanography Centre, Empress Dock, Southampton, SO14 3ZH	Phone: +44 (0) 1703 596046 Fax: +44 (0) 1703 596066 E-Mail: peter.j.mason@soc.soton.ac.uk
Miller, G W J Head of Scientific Instrumentation Group	NERC, Research Vessel Services	Southampton Oceanography Centre, Empress Dock, Southampton, SO14 3ZH	Phone: +44 (0) 1703 596017 Fax: +44 (0) 1703 596279 E-Mail: bill.miller@soc.soton.ac.uk.
Miyazaki, T	Nippon Marine Enterprises	14-1 Ogawa-Cho, Yokosuka, 238 JAPAN	Phone: +81 468 24 4611 Fax: +81 468 24 6577
Ober, S Instrumentation Engineer	NIOZ, Netherlands Institute for Sea Research	PO Box 59, 1790 AB Den Burg, Texel, The Netherlands	Phone: +31 (0) 222 369413 Fax: +31 (0) 222 319674 E-Mail: ober@nioz.nl

Palmer, S Sales Manager	Oceano Instruments (UK) Ltd	9 New Brookpark, Edinburgh, Scotland, EH5 1RS	Phone: +44 (0) 131 552 0303 Fax: +44 (0) 131 552 6619 E-Mail: sales@oceano.demon.co.uk
Phipps, R Scientific Engineer	NERC, Research Vessel Services	Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH	Phone: +44 (0) 1703 596312 Fax: +44 (0) 1703 596066 E-Mail: raphi@soc.soton.ac.uk
Pike, A	University of Edinburgh	Dept of Geology & Geophysics Marine Geosciences Unit, West Mains Road, Edinburgh EH9 3JW	Phone (0) 131 650 1000 Fax: (0) 131 668 3184

Polet, H Fishing Gear Technologist	Fisheries Research Station	Ankerstraat 1, 8400 Oostende, Belgium	Phone: +32 59 320 805 Fax: +32 59 330 629 E-Mail: hpolet@umicall.be
Pollentier, A	M.U.M.M. Ministry of Environment	Liniregiments Plein, 8400 Oostend, Belgium	Phone: +32 59 700 737 Fax: +32 59 704 935 E-Mail: bmmost@camme.ac.be
Polman, W	NIOZ, Netherlands Institute for Sea Research	PO Box 59 1790 AB Den Burg, Texel, The Netherlands	Phone: +31 (0) 222 369304 Fax: +31 (0) 222 369674 E-Mail: willem@nioz.nl
Read, J W Mooring/Current Meter Technician	M.A.F.F. Directorate of Fisheries Research	Main Laboratory, Pakefield Road, Lowestoft, Suffolk, NR33 0HT	Phone: (0) 1502 562244 Fax: (0) 1502 513865 E-Mail: j.w.read@dfr.maff.gov.uk
Ridout, P Managing Director	Ocean Scientific International	Southdown House, Station Road, Petersfield, Hampshire	Phone: (0) 1730 265015 Fax: (0) 1730 265011 E-Mail: osil@soc.soton.ac.uk

Robertson, K G Scientific Superintendent	NERC, Research Vessel Services	Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH	Phone: +44 (0) 1703 596215 Fax: +44 (0) 1703 596267 E-Mail: kenneth.robertson@soc.soton.ac.uk
Schilling, J Chief Technician	NIOZ, Netherlands Institute for Sea Research	PO Box 59, 1790 AB Den Burg, Texel, The Netherlands	Phone +31 (0) 222 369305 Fax: +31 (0) 222 319674 E-Mail: jack@nioz.nl
Sherring, A Scientific Engineer	NERC, Research Vessel Services	Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH	Phone: +44 (0) 1703 596052 Fax: +44 (0) 1703 596066 E-Mail: alsh@soc.soton.ac.uk

Smith, J Marine Technician	University of Edinburgh	Dept of Geology & Geophysics, Marine Geosciences Unit, West Mains Road, Edinburgh EH9 3JW	Phone: (0) 131 650 1000 Fax: (0) 131 668 3184 E-Mail: jim@glg.ed.ac.uk
Sorriabas, J Database Manager & System Administration	Instute de Ciencias del Mar	Paseo Juan de Borbon, S/N, 08039 Barcelona, SPAIN	Phone: +34 (3) 221 64 16 Fax: +34 (3) 221 73 40 E-Mail: jordi@beagle.geo.ub.es
Teare, D Instrumentation Engineer	NERC, Research Vessel Services	Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH	Phone: +44 (0) 1703 596224 Fax: +44 (0) 1703 596279 E-Mail: dte@soc.soton.ac.uk

van Bergen Henegouw, C N	NIOZ, Netherlands Institute for Sea Research	PO Box 59, 1790 AB Den Burg Texel, The Netherlands	Phone: +31 (0) 222 369452 Fax: +31 (0) 222 319 674 E-Mail: bergen@nioz.nl
Waddington, I	George Deacon Division for Ocean Processes	Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH	Phone: +44 (0) 1703 596373 Fax: +44 (0) 1703 596382 E-Mail: inw@soc.soton.ac.uk
Winterburn, R	Marine Environmental Systems	PO Box 179, Woking, Surrey GU22 0EF	Phone: +44 (0) 1483 776267 Fax: +44 (0) 1483 7687268 E-Mail: 100345.503@CompuServe.COM
Worrilow, S Senior Engineer	Woods Hole Oceanographic Institute	MS #30, Woods Hole, MA02536, USA	Phone: 001 508 289 2458 Fax: 001 508 457 2181 E-Mail: sworrilow@whoi.edu

Wynar, J Instrumentati on Engineer	NERC,Research Vessel Services	Southampton Oceanography Centre, Empress Dock, Southampton, SO14 3ZH	Phone: +44 (0) 1703 596221 Fax: +44(0) 1703 596279 E-Mail: jbwy@soc.soton.ac.uk