INTERNAL DOCUMENT

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DEACON LABORATORY

A REVIEW OF THE INSTRUMENTATION REQUIREMENTS FOR LRP1

G GRIFFITHS

NOVEMBER 1989

IOSDL INTERNAL DOCUMENT NO. 289

Natural Environment Research Council

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DOCUMENT DATA SHEET

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TITLE A Review of the Instrumentation Requirements for LRP1	
REFERENCE IOSDL Internal Document 289	

ABSTRACT

This review has been based on the parameters and processes that need to be observed as part of LRP1 - 'Processes determining the structure of the upper ocean'. Primary instrumentation systems are identified for each requirement area - shipboard, insitu and remote sensing.

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KEYWORDS Instrumentation Measurements Equipment LRP1	*CONTRACT* *PROJECT* *PRICE*

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1. INTRODUCTION

The purpose of this review is to address the instrumentation requirements of the MPD laboratory project LRP1 - ' Processes determining the structure of the upper ocean '. The review has been driven by the parameters and processes we wish to observe. Existing instrument systems available at IOSDL figure prominantly in the analysis, as would be expected given our history of successful observations in many of the areas considered. Furthermore, systems currently at various stages of development are seen to have a significant, coherent contribution to make to the aims of the LRP. Other systems are of secondary importance and clear decisions have to be taken regarding their future. Some specific recommendations are made for each of the three areas studied: Shipboard, In-Situ and Remote Sensing.

As a starting point, outline hierarchical diagrams of processes and parameters for the three instrument areas were distributed to the team members. Their comments, suggestions and additions were incorporated into the original diagrams to form Figures 1 2 and 3. Based on these diagrams instruments were identified for each 'box' and brief comments made. Collecting together these instrument references showed that several systems coupled together would be capable of providing the majority of the observations needed for the LRP. These systems are then described in more detail, shortcomings in presently available instruments are noted and actions suggested where appropriate.

A brief review of process scales in time, in the vertical and horizontal follows which emphasizes the types of instruments with the necessary time and spatial measurement capability. The study concludes with a set of general recommendations, the main ones being:

a) development of an advanced thermistor chain to be towed beneath SeaSoar

b) modernise our stock of current meters and thermistor chains

c) consider purchase of insitu ADCPs and profiling CTDs

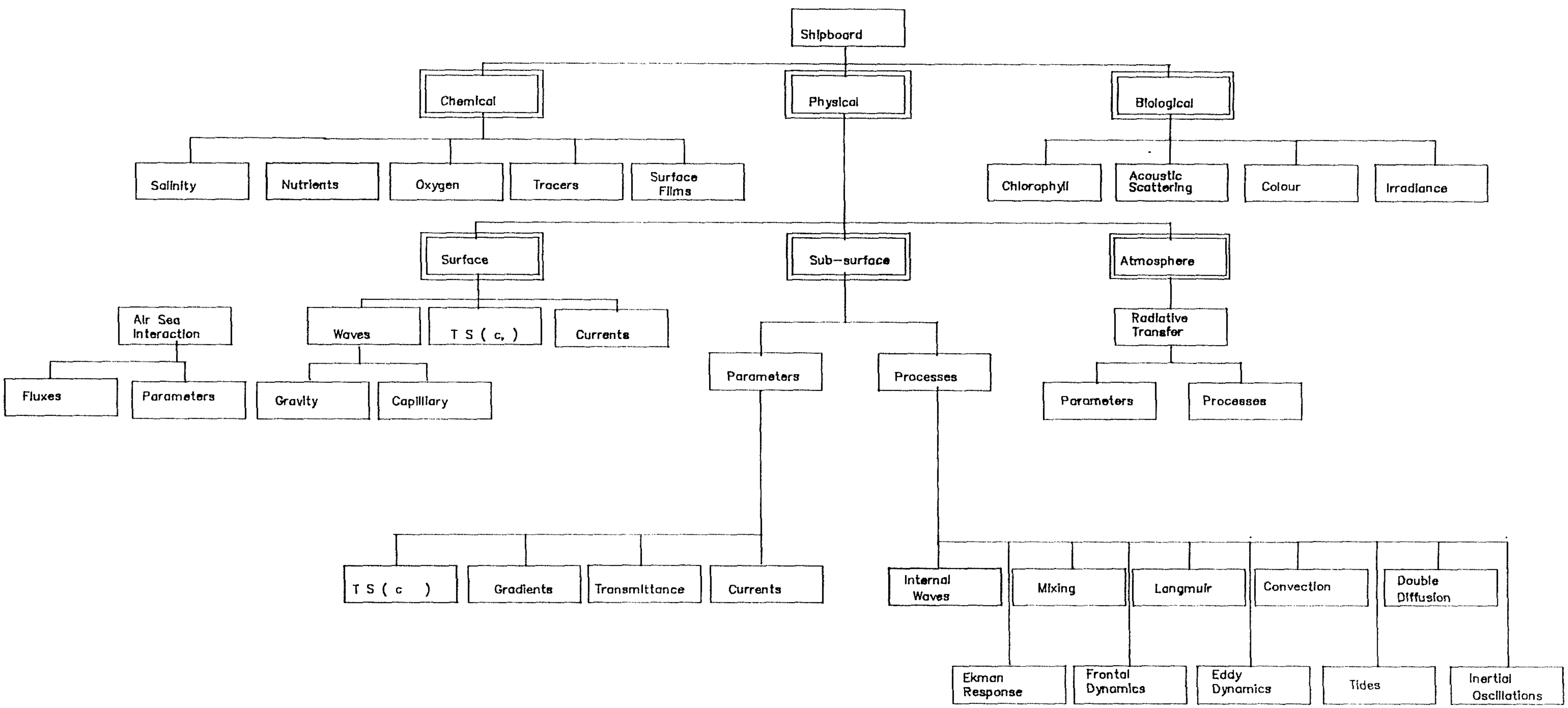
d) examine ATTOM development for near surface use

e) develop innovative moorings / mooring arrays

f) progress rapidly with the stereo-photography project.

Some specific items have already been listed for the 1990/91 estimates. A forward look for 1991/5 proposes other instruments, though this latter is mainly restricted to cover my personal areas of expertise.

2. Shipboard Instrumentation



2. SHIPBOARD INSTRUMENTATION

CHEMICAL

Salinity	Guildline Autosal salinometer Reliable instrument given regular maintenance. Trained users for best results. New instrument to be purchased in 1989/90.
Nutrients	Chemical methods / Autoanalyser
Oxygen	Chemical titration Accuracy needs to be improved. Trained users for best results. J. Read has investigated upgrading the MPD Oxygen titration equipment
Tracers	CFC analysis. D. Smythe-Wright at IOSDL, A Watson at PML. Freon 11 and 12 more straightforward than Freon 113, Carbon Tetrachloride is another possible tracer.
Surface films	No capability known at IOSDL, though it has been done (D Smythe-Wright at Liverpool). Perhaps important for stereo-photography of capillary waves.

Little OIG support (needed) to MPD in these areas. Some support from Chemistry. Salinometer support from Ocean Scientific International.

BIOLOGICAL

Chlorophyll	Shipboard/towed fluorimeters Aquatraka from CI Turner fluorimeters available for use off the ship non-toxic supply. Chart recorder output, but can also be logged.
Acoustic Scattering	ADCP (RDI shipboard) With care and perhaps some modifications it can give quantitative measurements of biota. See Flagg and Smith, DSR Vol 36 No 3 pp 455-474 (request into RVS this year for mods to enhance the ADCP in this area). HF Echo Sounder.
Ocean Colour	No capability at IOSDL Expertise at PML (Aitken) and SUDO (Boxall).
Irradiance	Has been used at IOSDL (H. Roe and M.J. Harris) Expertise at PML (Aiken, Pingree).

Fluorimeter supported by OIG (SeaSoar). Primary ADCP support is through RVS.

PHYSICAL - SURFACE

Air sea interaction	Fluxes	Sensible heat Latent heat Precipitation Aerosols Stress (+ vorticity etc) - Fast Multimet
	Parameters	Air temp, bulk sea temp, humidity wind velocity, ship velocity, ship head, air pressure, ship motion - all covered by Slow Multimet
		Ocean roughness and skin sea temp not measured.

Instruments identified for purchase (by PKT):Humidiometer (IR), IR SST Radiometer (RAL), Sonic anemometer or hot wires. Others : opticalprecipitation sensor other humidiometers, hot wire temperature probes, aerosol probes, etc

This area is very well covered by Peter Taylor and receives significant OIG support for operations and development.

Waves	Gravity	Shipboard wave recorder Useful measurement.
	Capillary	Stereo-photography Significant, high profile innovative development for OIG and MPD.Early days, progress hampered by hardware problems.
T S C	Thermosalinograph	RVS support. Some reliability problems, has poor digitizing and hence tends to be neglected. Could be useful in extending SeaSoar data to the surface. Also used for drawing samples for SeaSoar calibration. Horizontal resolution down to a few metres. Calibration needs to be performed regularly. Surface sampling possible using a pumped supply to a CTD on deck, perhaps giving a better performance.
	Bucket measurements	No longer considered necessary.
Currents	Ship drift and navigation	Improvements in space/time resolution will occur with full availability of GPS. Although it would be technically possible to use an ADCP instead of the EM log more experience needs to be gained with the ADCP to use it for DR.

PHYSICAL - SUB-SURFACE

Parameters T S C

Lowered and towed NBIS MK3 CTD (with optional sensors eg O2). Significant OIG support for routine use and developments. Instruments and support also available through RVS.
These are the prime tools for LRP1 and WOCE. A Mk 5 instrument is to be purchased when they become available.

XBT - hardware available, probes have been provided in the past by MoD (50 in stock as at Oct 1989).

Whereas SeaSoar is likely to be the prime towed vehicle, the lesser cabability of CI's Aquashuttle should be investigated for use on passage (speed to 27kt, depths of 5 to 70m, 20 litre instrument space). SeaRover, on loan from Kiel to RVS may also be found useful.

Gradients

Not clearly defined as yet, but for example, there are times when the relative values are important and not their absolute values. This may be the case with thermistor chains.

Transmittance

Standard instrument is the Sea-Tech 1m path transmissometer.
Receives OIG support from the CTD team.

Currents

RDI Shipboard ADCP, installed on the 3 RVS vessels, with RVS support. Generally capable of acceptable performance if carefully calibrated.
Some residual problems with the Discovery instrument, perhaps caused by bubbles and the complex signal processing.

XCP probes are available, but are expensive. The same is true for the acoustically tracked Hydroball expendable probes. Devices such as the Miami wire guided profiler are available (eg as used by IOS in the Indian Ocean 1979), but are expensive on ship time,and operate on station only.

Processes	Internal Waves	Yo-Yo CTD SeaSoar (both t > 15 mins) HF echo sounder - not fitted as standard equipment, ARE unit usually borrowed gives trouble. Possible to use ADCP backscatter - needs investigating. Towed sidescan sonar - would require image processing - submitted as a MAST proposal with SUDO and WSL. XBT drops in rapid succession can be used - but expensive, minimum interval of 5-8 minutes. Lowered/towed thermistor chains for t < 15 minutes.
	Ekman	ADCP. Preferably on station during high winds (Darwin cruise 43 should prove interesting here - I've not seen a shipboard ADCP Ekman layer paper published)
	Mixing	SeaSoar/CTD - Statistics only ADCP - " Possibly an XBT/XCP combination. HF echosounders. Lowered/towed thermistor chains. Freefall CTD microprofiler. Dye/Fluorimeter techniques.
	Frontal Dynamics	SeaSoar/CTD. ADCP. XBT. Towed thermistor chains.
	Langmuir	SeaSoar (constant depth). Towed/lowered thermistor chains. ADCP. HF echosounders, towed sidescan.
	Eddy Dynamics	As Frontal Dynamics.

Tides	Tidal currents - ADCP + models. Complex - POL have experience of this from their N Sea work
Double Diffusion	Towed thermistor/conductivity measurements with vertical resolution of order 10cm. Freefall CTD microprofiler.
Inertial Oscillations	ADCP
Convection	SeaSoar upper 400m only Towed thermistor chains. ADCP.

PHYSICAL - ATMOSPHERE.

Radiative Transfer	Temperature Humidity Wind velocity	Radiosondes. Acoustic sounders, LIDAR and Doppler radar are other possible instruments.
	Aerosol Cloud/Water	No instruments available.
	Sub-processes	Shortwave Longwave Microwave

Radiosonde support is available through OIG.

SUMMARY

The histogram below shows the applicability of several shipboard instrument systems to the measurement requirements of LRP1.
It has been drawn up from the references to the instruments in the preceeding analysis, giving equal weight to each parameter or process.

CTD	SeaSoar	ES/SS	ADCP	TC	XBT	μ Profiler
x	x	x	x	x	x	x
x	x	x	x	x	x	x
x	x	x	x	x	x	
x	x		x	x		
	x		x	x		
	x		x	x		
			x	x		
			x			

CTD

Our old stock of NBIS Mk3 CTDs is being augmented by a new Mk5 unit as soon as possible. They are of vital importance to our measurement programme and should be included in a long term phased purchase plan.

SeaSoar

Again vitally important. Developments are envisaged to increase operational depth and to ruggedise and document the system.

Much of the success of SeaSoar is because the instrument forms part of a complete measurement system. This includes data processing and committed support and development coupled with a strong scientific requirement. This approach should be actively encouraged for future instrument developments, eg Stereo Photography, Thermistor chains.

Echo Sounders/ Sidescan

The remarks made on the insitu versions, p21 apply here also. Greater processing power will be available on board a vessel, and will be essential to make the task of Sonar interpretation manageable. However, mainly qualitative information can be obtained from simple, chart recorder type displays, eg for internal wave studies.

These instruments may well prove more useful as shipboard systems than as moored instruments because of the data processing/interpretation requirements. However, at present they mainly provide descriptive information, quantitative measurements will only be possible following significant developments in the signal processing eg our MAST proposal or the related work at Southampton.

ADCP — Of central importance, as a stand alone instrument and when coupled with SeaSoar. We are still gaining experience and insight and not all the problems have been overcome. I believe putting effort into furthering our understanding of the ADCP current data will be very worthwhile, from two viewpoints. Firstly, we need more experience of the instrument and its shortcomings. Secondly, we need to use it to advance our science. It has some potential as a digitally recording HF echo sounder which will repay some further examination.

XBT — Standard system, whose reliability could well be improved.

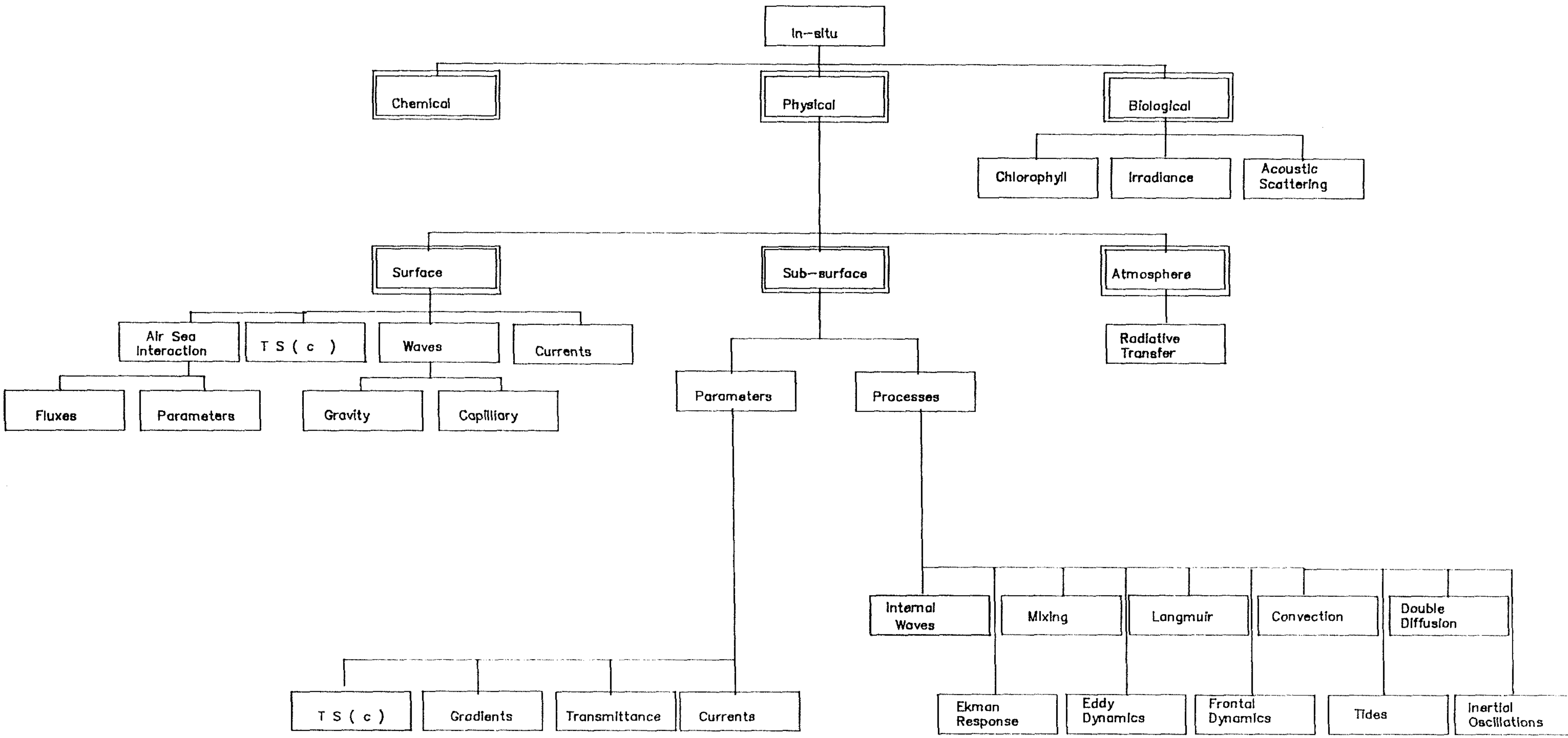
Therm. Chain — Potentially valuable in several areas:

i) towed near the surface eg towed spar
ii) towed long chain with a depressor eg ARE chain
iii) towed in conjunction with SeaSoar.

Option (iii) is particularly exciting and would contribute significantly to measurements of several processes. A detailed specification should be written for a complete system, including all aspects of data acquisition and processing.

μProfiler — Useful for the study of small scale phenomena. Our lack of experience of this type of measurement would require significant time to be spent on the inevitable practical problems involved.

3. In-situ Instrumentation



3. IN SITU INSTRUMENTATION

CHEMICAL

No present MPD LRP requirement for insitu chemical measurements, other than salinity which is considered a physical measurement ie calculated from conductivity.

BIOLOGICAL

Chlorophyll	Moored fluorimeter available from CI, either as a stand alone instrument or combined with a current meter and CTD. No known use at IOSDL yet.
Irradiance	Significant experience at PML (Aiken).
Acoustic Scattering	Most likely to be obtainable from moored ADCPs, useful qualitative data but would need a significant effort to give quantitative results

PHYSICAL - SURFACE

Air sea interaction	Fluxes	requirements as shipboard, no plans yet to implement Fast Multimet on a buoy
	Parameters	requirement as shipboard, Slow Multimet is being adapted for mounting on a buoy. At present a sub-set of the requirements can be met by the Aanderraa met buoy.

Achieving a high reliability met buoy based on Multimet will involve significant effort from the OIG section concerned.

Waves	Gravity	Datawell WAVEC, a moored directional wave buoy, mooring becomes more complex in depths of greater than 1000m. Pitch Roll buoy, free drifting therefore not limited by water depth, but short endurance, about 3hrs, and can overturn in heavy seas.Ship attendance is usually advised S4 current meter has an optional directional wave processing capability.
	Capillary	No known insitu instrument, but some preliminary thoughts have been given to this area in conjunction with the stereo photography project.
T S C		Surface buoys with suitable sensors.
Currents		Surface buoys with suitable sensors. eg VAESATs at 1m and 2m. ADCP available on the 1m VAESAT. Difficulty of interpretation of surface following buoy current data. Surface drifters (eg SPEFF floats, ARGOS buoys), these give Lagrangian measurements which may not be representative of large scale currents, eg in the presence of fronts or Langmuir circulation. Near surface acoustic tracking is expensive on ship time - typical ranges being less than 10km. Argos buoys can be cost effective and modern developments using onboard Decca (GPS ?) receivers can give better resolution in time and space.

In general these areas are well served by OIG/MPD support. Waves and surface currents were a major focus for OIG innovative developments.

PHYSICAL - SUB-SURFACE

Parameters	T S C	Suitable sensors on current meters, eg Aanderaa, VACM (S4, VMCM, Aquasensor) Special T S probes, eg Sensordata. Thermistor chains (possibly with some conductivity sensors). BERTHA. Mechanical T S profilers, eg instrument developed at CSD Labs at MIT as used by C.Eriksen. ATTOM may well be able to provide a remote sensing method of measuring C, thereby T and V. However its use near surface will increase the difficulties in interpreting and processing the data.
	Gradients	Thermistor chains. BERTHA.
	Transmittance	SeaTech transmissometer, short path transmissometer on the CI Aquasensor.
	Currents	Large choice of current meters, eg Aanderaa, VACM (obsolete), VMCM, S4, Aquasensor, Simrad, Suber etc. Profilers, mechanical and ADCPs. Integrated long path, ATTOM[1] , tomography. Lagrangian floats.

Standard current meters are supported by MPD. Full use should be made of the Aanderaa capability for conductivity measurements. The VACMs are obsolete. A phased purchase of modern, high performance current meters should be planned over the next five years. This plan should include in-situ ADCPs.

Mechanically profiling T S instruments should be investigated further - the CSD Labs instrument is not available commercially, a single instrument would cost about $200k - pers comm. - J Dahlen MIT.

Although ATTOM has been designed as a deep water, deep sound channel instrument, there is no fundamental reason why the technique cannot be used in shallower water and or in near surface situations. There will undoubtedly be problems associated with this, including signal processing and interpretation, existence of suitable sound channels and the effects of mooring motion. The latter problem can be solved by monitoring the mooring using a system such as the Marine Acoustics self-contained, self-calibrating navigation system which will be available at IOSDL later this year. At this stage of its development ATTOM should not be ruled out as unsuitable for near surface use, rather the innovative and challenging aspects of its use under such conditions should be investigated. In addition, the scientific benefits should also be addressed.

Processes	Internal Waves	Current meters. Mechanical T S profilers Thermistor chains, BERTHA. ADCPs. Inverted echo sounders, sidescan sonar, subject to data capacity/on-board processing limitations.
	Mixing	Thermistor chains, possibly with conductivity sensors. T S profilers. Coherent ADCPs, promising current resolutions of ~ 3mm/s at 1Hz (perhaps two years away). ARIES.
	Langmuir	Thermistor chains. ADCPs especially coherent. Inverted echo sounders and sidescan sonar.
	Double Diffusion	Mechanical T S profilers, would probably need to be 'intelligent', eg to change their profiling speed dependent on the density gradient.
	Ekman Response	Drifting spar with current meters. Lagrangian floats with drogues. ADCPs.
	Eddy Dynamics	Drifting spar with current meters plus spar location. Standard current meter moorings. Lagrangian floats with drogues. Thermistor chains. ADCPs. (ATTOM?)
	Frontal Dynamics	As Eddy dynamics plus T S profilers. Special mooring array designs.
	Tides	Level - sea bed tide gauges. Current - Current meter moorings, ADCPs.
	Inertial Oscillations	Current meter moorings, drifting spar plus current meters plus location. ADCPs. (ATTOM?) Lagrangian floats.
	Convection	Thermistor chains, T S profilers. ADCPs. Current meters with temperature sensors.

SUMMARY

The histogram below shows the applicability of several insitu instrument systems to the measurement requirements of LRP1.

CM	TSP	TC	ADCP	IES/SS	FLOATS	ATTOM	T GAUGE
x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	
x	x	x	x	x	x	x	
x	x	x	x		x		
x	x	x	x				
x		x	x				
x			x				
			x				
			c				
			c				

c - coherent ADCP only

This list clearly shows that a small number of generic classes of instrument systems can provide the insitu sub-surface physical measurements that are needed.

Current Meters

1. Not all our present instruments have conductivity sensors. Aanderaa sensor accuracy and stability is adequate for water mass identification in frontal areas.

2. Non-Aanderaa stock is very dated and needs modernising on a phased planned basis. Small low drag lightweight units such as the S4 will ease near surface mooring design problems.

T S Profilers

1. Expensive, but can make useful contributions to the measurement of several processes - needs further investigation.

Thermistor chains

1. Important for several process measurements. Two coarse spatial/temperature resolution chains of 200/400m are being augmented this year with two 100m chains with better resolution. Further additions to our stock should be planned over the next 5 years.

2. Following experience gained with the shorter chains , other more specialised versions may be required, eg bunched or non-uniform sensor spacing.

ADCPs

1. The present in house in-situ capability is limited to two short range (20m) versions. They are of specialised use.

2. POL have designs for 250 and 75kHz versions. The 250kHz versions have been sucessful in the N Sea but are limited to 320m depth. The 75kHz unit has yet to be tested.

3. This review clearly shows that ADCPs have a strong contribution to make in several important areas of our measurement programme. Purchase should be considered as part of a coherent long term plan of reinvestment in new instruments.

4. A watch needs to be kept on developments of coherent ADCPs. Such instruments would be useful for small scale process measurements. RDI are actively working on the severe signal processing problems of this method.

Inverted Echo Sounders/ Sidescan sonar

1. These provide qualitative information though they are capable of quantitative measurements.

2. With SUDO and WSL we are involved in a MAST proposal to develop a digitally recording sidescan sonar as a first step towards image processing and feature recognition and measurement.

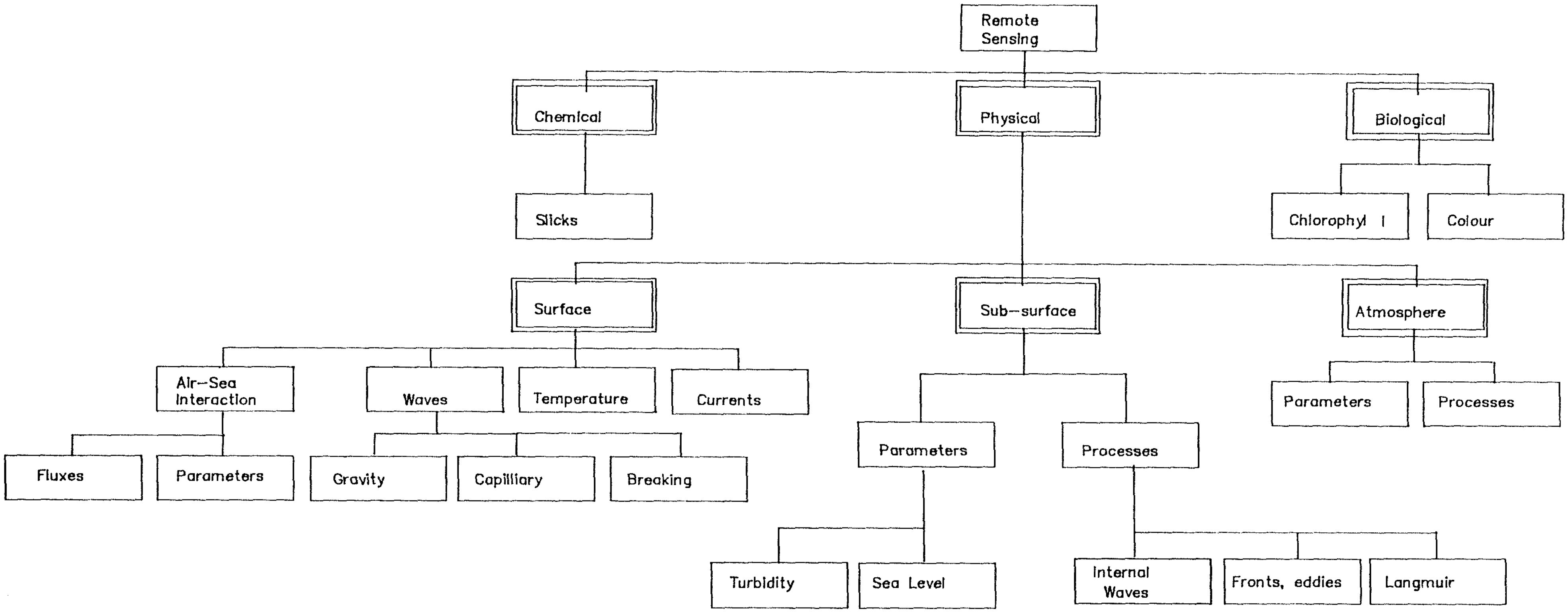
3. ARIES is a specialised IES for bubble cloud measurements. Careful thought should be given to the direct benefits it can bring to LRP1 for the resources it requires. Can technicians at Soton be trained in its preparation/use?

Lagrangian Floats

1. Historically very important to IOSDL, with strong OIG support to MPD. Now less useful to LRP1 than other instrument systems - though they may have some use in the determination of circulation patterns over large areas.

ATTOM	1. An important innovative instrument for OIG/MPD. Signal processing / interpretation still needs development. This is a challenging area for both MPD or OIG. Whilst the instrument has still to be proven there are sufficient grounds for a short study to examine its potential usefulness to upper ocean observations.
Tide gauges	1. Mature technology at POL.

4. Remote Sensing



4. REMOTE SENSING

CHEMICAL

Slicks	SAR imagery shows slicks, presumably due to surface pollution causing changes in the sea surface roughness at centimetric wavelengths.

BIOLOGICAL

Chlorophyll Colour	Chlorophyll and other pigments in surface waters can be seen in the images of the CZCS. AVHRR images also show phytoplankton blooms.

PHYSICAL - SURFACE.

Air Sea	Fluxes	Measurements of rain, rain rate and wind stress are possible by satellite.
	Parameters	Wind velocity and direction can be measured by a scatterometer. Sounders can measure surface pressure.
Waves	Gravity	Measured by altimetry, long period waves can be seen on SAR images.
	Capillary	Important in providing the scattering mechanism for the active microwave sensors: SAR,altimeter and scatterometer.
Temperature		Skin temperature measured by IR radiometers. eg AVHRR whose images received at Dundee can be sent to research ships.
Currents		Altimeter, SAR, CZCS On the large scale geostrophic currents can be calculated from sea surface elevations . Mesoscale variability of currents can be obtained without knowing the geoid precisely. Feature tracking can be used in frontal/eddy regions to infer currents, given good image registration. Wave refraction seen in SAR images can be related to current shear. CZCS images show filamented structures where biological material acts as a tracer.

PHYSICAL - SUB-SURFACE

Parameters	Turbidity	CZCS images show turbidity flows especially in estuaries and other very turbid waters.
	Sea Level	From altimetric measurements sea level and tidal information can be obtained.
Processes	Internal Waves	SAR and AVHRR images.
	Fronts, Eddies	SAR and AVHRR images.
	Langmuir	SAR images.

PHYSICAL - ATMOSPHERE.

Parameters

Temperature profiles, water vapour, cloudiness, short- long- and microwave radiation can be measured using various sensors.

SUMMARY.

The histogram below shows the applicability of several satellite remote sensing instruments to the measurement requirements of LRP1.

SAR	AVHRR	Altimeter	CZCS	Scatterometer	PM
x	x	x	x	x	x
x	x	x	x		x
x	x		x		x
x	x				
x	x				
x					

SAR — Qualitative images needing careful interpretation. Potentially very valuable given more validation work. Particularly useful for the surface signatures of sub-surface processes such as internal waves, fronts, eddies and Langmuir circulations. No weather dependence. Data exists for the JASIN area, techniques such as feature correlation will prove a fruitful line of research.

AVHRR — Well understood temperature and chlorophyll images, but the area needs to be free of cloud. Transmission of the images to ships is possible.

Altimeter — Important for the measurement of sea level currents and waves. MPD has great expertise in the interpretation of altimeter data.

CZCS — This is used as a generic term for Ocean colour sensors. The capability here is for qualitative measurements.

Scatterometer — Measurement of surface wind.

Passive Microwave — Necessary for the correction of atmospheric affects on altimeters. Advantage of all weather SST coverage, useful in Iceland Faroes region, but the resolution remains low. The salinity measurement is of little value due to its low resolution. An additional measurement is that of ice-edge position.

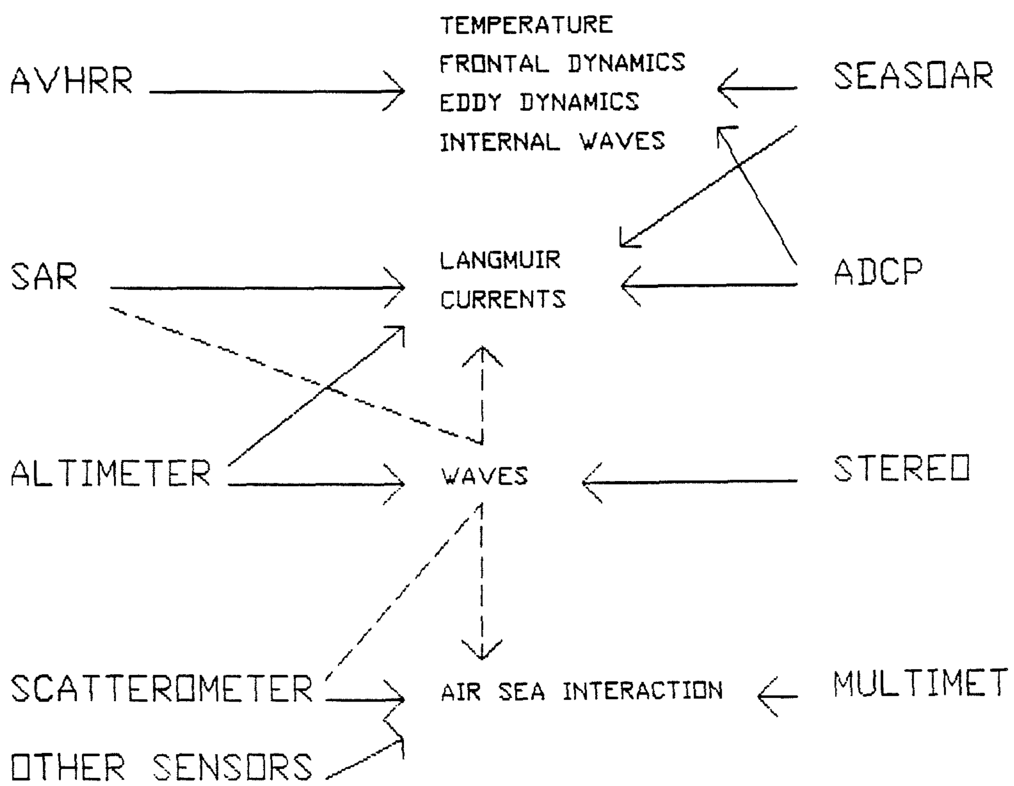
Sensor availability.

SAR	ERS-1, RADARSAT
AVHRR	MOS-1, ERS-1
Altimeter	GEOSAT, MOS-2, ERS-1, TOPEX/POSEIDON
Scatterometer	MOS-2, ERS-1.
Passive Microwave	DMSP, MOS-1, ERS-1, TOPEX/POSEIDON

The diagram below shows the relationship between satellite remote sensing and the prime shipboard instruments. Solid arrows represent the direct research into the physical phenomena wheras the dotted lines show that the SAR and the scatterometer (as well as the altimeter) rely on interaction with waves.

Thus we have a dual focus, firstly the use of satellite remote sensing directly as part of the observations of the ocean physics, and secondly the nature of the interaction of microwaves with the ocean surface at centimetric wavelengths.

Satellite data interpretation and data assimilation is receiveing high priority in terms of manpower and other resources within MPD. As an innovative project in this important area , the stereo photography of the sea surface is as demanding as the other prime areas of MPD instrumental activity.



PROCESS SCALES

Process	Time Scale	Vertical Scale (m)	Horizontal Scale (m)	
Internal waves	mins-hours	1-full depth	$10 - 10^5$	sAT
Ekman response	hours	to MLD	$>10^4$	A
Mixing/Stats	secs	$10^{-2}- 10$	$10^{-2}- 10^2$	T
Front Dynamics	mins-days	$10 - 10^3$	$10 - 10^5$	SAT
Langmuir	minutes	MLD	$10 - 10^3$	saT
Eddy Dynamics	hours-days	$10^2- 10^3$	$10^4 - 10^5$	SAT
Convection	secs-hours	$1 - 10^3$	$1 - 10^4$	sAT
Tides	hours	full depth	10 - 10	A
Double diff.	secs-mins	$10^{-1} - 10$	$10^2 - 10^5$	saT
Inertial Osc.	hours	MLD-full depth	$10^4 - 10^5$	A

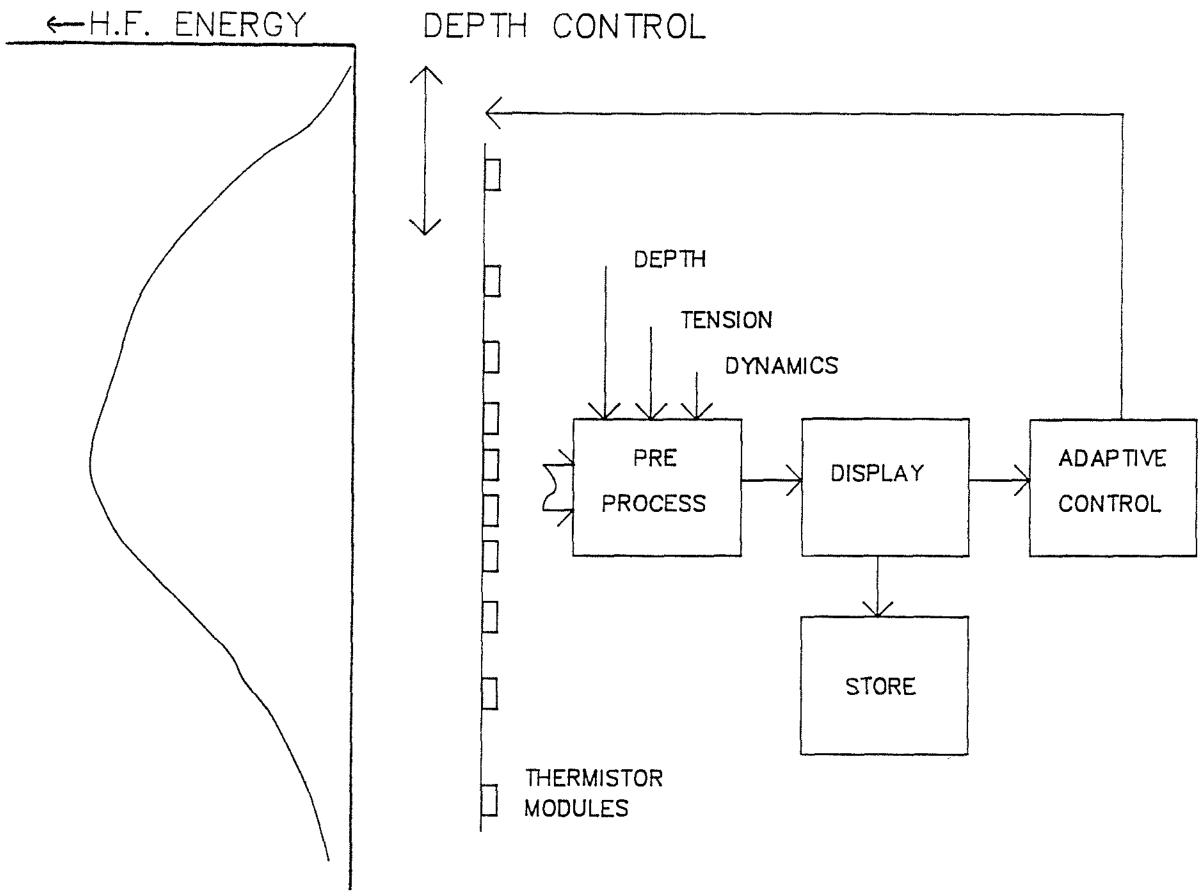
Summary of entries: Primary 2S 7A 7T
Secondary 4s 2a

Key to instruments

S - SeaSoar has primary capability
s - SeaSoar has secondary capability
A - ADCP has primary capability
a - ADCP has secondary capability
T - Thermistor chain

The table confirms the important role of the three instruments in studying the upper ocean. Frontal and eddy dynamics are presently well covered by the primary capability of SeaSoar and the ADCP. Other processes can be studied on a secondary basis with SeaSoar, either by accepting sub optimum resolution or by adopting special towing profiles eg slow ramps or adaptive control. Wherever SeaSoar has a primary or secondary capability a thermistor chain can also be used. By enhancing SeaSoar the thermistor chain provides a more complete picture of the processes being studied. In the case of Mixing/SSA where the SeaSoar does not provide measurements, an attached thermistor chain may be able to do so. The design of such a chain should aim to be innovative by including features such as adaptive depth control and online data processing, see diagram below.

ADCPs have a clear potential to provide measurements to study these processes. However, given that it is a relatively new instrument work needs to be done to translate this potential into practice. Some of the better quality ADCP data that we have can be used for this purpose as well as the data to be gathered this autumn on the two MPD cruises on RRS Charles Darwin.



Example of an adaptive thermistor chain for observing 'pancake' mixing.

6.0 RECOMMENDATIONS

1. Instruments and instrument systems should be categorised according to their importance to LRP1 objectives. This should take into account factors such as :

    i) importance to the scientific objectives
    ii) support throughout the data chain including: technical field support, inhouse and manufacturer, data gathering, online processing, post processing, and data interpretation.
    iii) The risk factors inherent in developing a new instrument inhouse should be fully explored.

2. Each category of instrument should have a planned purchase and replacement strategy spanning at least the life of the project. Major purchases such as NBIS CTDs, RDI ADCPs and major inhouse developments such as a towed thermistor chain can then be flagged well in advance. Furthermore, the context of the strategic requirement for such instruments can then be clearly set out.

3. Areas identified in this report for purchase and developments are as follows:

i) Shipboard	Primary	ASI Fluxes and parameters. SeaSoar enhancements - depth capability, reliability and, of prime importance, the addition of a thermistor chain, possibly including conductivity sensors. ADCP processing on board ship should be developed to a routine as is the case with SeaSoar.
	Secondary	Further evaluation of the RDI ADCP, including its use as an HF echo sounder. Enhance SeaSoar for biological measurements eg optical sensors. Qualitative use of HF echosounders.
	Tertiary	Examine the use of XBT/XCP combination, microprofilers and fast response current meters for mixing studies.Quantitative use of echosounders and sidescan sonars.

ii) Insitu	Primary	Modernise our current meter stock with high performance instruments, eg S4, VMCM. Make more use of thermistor chains. Design innovative moorings eg inverted U cross frontal ADCP/Current meter and thermistor chains. Consider purchase of insitu ADCPs.
	Secondary	Consider purchase/development of mechanically TS profilers. Quantitative use of echosounders and sidescan sonar. Examine the possible roles of ATTOM and drifting buoys in LRP1.
iii) Remote Sensing	Primary	Ensure adequate financial and manpower resources are available to the stereo photography project. Develop in situ method of capillary wave sensing to assist in validating the stereo photography measurements. Maintain and advance our cabability of making insitu measurements for satellite cal/val purposes eg shipboard radiometers for SST.
	Tertiary	Examine the feasibility of using shipboard sounders and radars for atmospheric measurements to validate satellite measurements.

7. FORWARD LOOK

Instruments are categorised using the scale - A essential, B - desirable and C - nice if for the years 1990-1995. A phased plan of instrument re-equipment and modernisation on a 5 year basis forms an important part of this forward look.

Item	90	91	92	93	94	95
S4 EM Current Meters (2 x 20K)	B ->	A	C		B	
In-situ ADCP (1 x 60K)	C ->	B ->	A			B
SeaSoar Thermistor Chain (100k)	A			C		
Aanderaa Therm chains (2 x 6k)	A	A	A		A	
Aanderaa RCM8 (4 x 5k)	A	A	A	A	A	A
Profiling CTD (125k)	B	A		B		
Microprofiler (25k)		C				
Digital Sidescan (40k)		C				
Coherent ADCP (100k)					C	
In-situ Capiliary waves (15k)			B			
Optical sensors - SeaSoar (15k)	C	B	A			
XCPs (10k)				C		
HF Echosounder (10k)		B				
ARGOS/GPS Buoys (5 x 4k)		C				

									TOTAL
Costs (k)	Category	A	120	197	92	47	20	38	514
		B	165	70	30	125	40	60	490
		C	75	85	40	100	110	0	410

Note- some items are moved up in priority from year to year (->), generally in order to fulfil presently assumed cruise needs. Such instruments would undoubtedly be useful in earlier years for the LRP and also, in some cases for WOCE.