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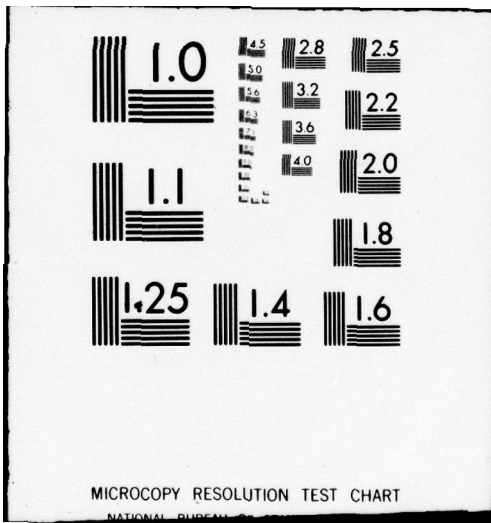
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WHOI-79-71

THE HEBBLE II REPORT

PROCEEDINGS OF THE SECOND ANNUAL WORKSHOP ON THE
HIGH ENERGY BENTHIC BOUNDARY LAYER EXPERIMENT
HELD AT THE
KEYSTONE CENTER FOR CONTINUING EDUCATION

MARCH 19-24, 1979

EDITED BY

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AUGUST 1979

TECHNICAL REPORT

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C. L. Roy Smith for J. I. E.
J. I. Ewing, Chairman
Dept. of Geology & Geophysics

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INTRODUCTION

In 1978, the first Keystone Conference addressed the scientific problems of sediment transport in a high energy flow such as the Western Boundary Undercurrent. Sedimentologists, physical oceanographers, geologists, optical oceanographers, biologists, and ocean engineers planned a program called the High Energy Benthic Boundary Layer Experiment (HEBBLE) to measure ocean floor bed-forms, sediment properties, turbulent flow structure, suspended sediment concentrations and fluxes, mixed layer thickness, outer scale velocity and horizontal gradients of density in a carefully surveyed site yet to be selected. While measurements were suggested, specific instruments were not identified to implement them. It was encouraging that the scientists participating in the first HEBBLE Conference wanted to continue to plan a multi-disciplinary experiment.

Because of the Jet Propulsion Laboratory's experience in management of planetary science experiments, autonomous instrumentation, image processing and data handling, we invited them to develop our experimental plan. Conferences were held in September at Woods Hole and November, 1978 at JPL to develop the instrumental ensemble. JPL involvement was concentrated on the extended deployment part of HEBBLE: the 6-month experiment. The March 20-23, 1979 conference brought JPL engineers and managers, HEBBLE scientists and PI's, ONR and NASA program managers together in Keystone, Colorado for presentation and discussion of the JPL program plan. This report summarizes the conference and includes reports by subcommittees of the conference on measurements and data sampling.

SCHEDULE

Tuesday, March 20, 1979

Introductions by Hollister, Williams, and Edberg
Presentation of JPL System Plan by Frewing
Presentation of HEBBLE Program Plan by Jaffe
Science Liason, Collins
Communications Systems, Brunstein
Power Systems, Frewing for Decker
Mechanical Systems, Laumann
Data and Control, Rubin

Tuesday afternoon

Assembly and Testing, Frewing for Danley
Meetings of subcommittees on the Bottom Mixed Layer,
Imaging, Sediment Property Definition, Current
Sensing, and Conditional Sampling

Tuesday evening

Discussion of the role JPL should play in HEBBLE
Meeting of Program and Project Managers to discuss agency
objectives and HEBBLE management

Wednesday morning, March 21, 1979

Discussion of JPL Plan and ways to eliminate unnecessary
complication or to increase scientific and technical benefit.
Particular topics included: real time video data link,
measurement of sediment properties, current meter
configuration, alternatives to event detection.
Deep sea bedforms and deep current systems, Hollister
Kretchmer's thin film heated current sensor, Williams
URI flume and sediment sampler, Silva
Holographic particle settling velocimeter, Carder
Pore water chemistry, Fanning

Wednesday afternoon

Meetings of subcommittees on the Bottom Mixed Layer,
Current Sensing, Suspended sediment, Real Time Telemetry,
Imaging

Wednesday evening

Discussion of conditional sampling: is it really needed?
Configuration of vertical array and outstations
Assignment of sensor responsibility
Strategy meeting of Project Managers

Thursday morning, March 22, 1979

Power Systems, Decker
Assembly and Testing, Danley
Time-lapse movies of Manop areas, Biscaye
Description of boundary layer turbulence, Collins
Information needs for JPL Plan, Frewing
Discussion of configuration and instrument definition

Thursday afternoon

Hard consideration of low cost alternatives and fall back positions.

Thursday evening

Discussion of fall back position and scientific and technological reasons for more advanced system

Vote on critical paths: Conditional sampling-required, radio link not yet

Friday morning, March 23, 1979

Seabed Disposal Heat Flow Experiment, Anderson
Baseline Engineering Assumptions and Options for JPL Plan, Frewing
Subcommittee Reports and Discussion
Conditional Sampling, Irish
Imaging, Wimbush
Sediment Property Definition, McCave
Suspended Particulate Measurement, Biscaye
Bottom Mixed Layer, Williams
Current Sensing, Williams

Friday afternoon and evening

Writing of Subcommittee Reports
Review of baseline JPL plan and planning of next review of technical and scientific progress

Saturday morning, March 24, 1979

Submission of Subcommittee Reports
Summary

SYNOPSIS OF DISCUSSIONS AND EVOLUTION OF
ENGINEERING REQUIREMENTS

JPL Plan, Appropriate JPL Involvement, NASA/JPL Technology Transfer

Following suggestions by the November/December 1978 conference at JPL, a plan was developed and a rough cut budget prepared for 9 landers of 4 types to remain deployed 6 months, intercommunicating acoustically and storing data at various rates on a central recorder. A critical review of the areas where required technology could only or best be provided by JPL showed that the outstations (consisting of vertical arrays of current meters, density sensors, and nephelometers) could be assembled with existing oceanographic technology. The profiling winch, with sensors of density, velocity and suspended particulates, was deemed not essential for the baseline experiment although it was recognized that it would be important for a study of the mixed layer. The central instrument cluster (the Master Lander), involving most of the PI's and a wide range of measurement requirements, did seem to require the technology of JPL. The particular areas of JPL expertise needed were systems management, mechanical systems for deployable arms etc., telemetry ashore, data processing and recording, (possibly) power sources, power conditioning and distribution, and future expansion of the capability of this instrumentation. It appeared that the restriction of JPL involvement to the single array requiring their kind of technology would be the best utilization of resources.

The development of a National Facility for BBL studies, which would include the HEBBLE Master Lander, would be a proper technology transfer of NASA/JPL capabilities to the oceanographic community. The equipment would be scheduled by a HEBBLE committee and the facility staffed by personnel from an oceanographic institution. Technology to be transferred would include learning to organize a multi-disciplinary common-lander experiment; assembly, maintenance and testing procedure of the lander; and technologies used in mechanical, data, power and communication systems (see following pages).
Conditional Sampling

A theme of many discussions was conditional sampling or event detection. The principle of allocation of data storage capacity to high sampling rates for intermittent phenomena was very attractive for most participants. However the criteria proposed to change the sample rate were disputed. It was also questioned whether conditional sampling was needed at all.

As a starting point, it was pointed out that all measurements could be recorded at a 5 minute sample rate for 6 months with a recording capacity of 10^9 bits. However, several investigators wanted to take measurements at a 10 sec sample rate during events. Photographs could not be taken as often as liked in a continuous mode. Thus it was felt by most people that conditional a sampling capability should be provided, even if it were not used initially.

Real Time Telemetry

In previous discussions, a video camera was to have been a part of the event detecting package; its purpose being the real time recognition of bedform changes. However, the image was expected to change for irrelevant phenomena as well, such as marine "snow" or crab activity, and only a small number of such phenomena were worth sampling. The complexity of defining which changes were bedform-related discouraged us from relying on autonomous detection. However it was proposed that a video data link to shore would permit one to identify real bedform changes and trigger the event mode of data sampling.

Such a data link could use electric cable from the lander to the surface, a radio link to a satellite, and a satellite receiver at a shore laboratory. The technology needed is available or under development. A subsurface buoy containing most of the buoyancy needed to float the electro-mechanical mooring line as well as a slack line from the subsurface buoy to a surface radio float are being developed under the ADOM (Air Dropable Ocean Mooring) program. Tiros or Nimbus satellites could relay the data to a shore facility. The cost of the shore facility would be substantial and the continuous manning of the viewing station might be difficult. Automatic detecting algorithms with alarms for the shore station were suggested but suffered in part from the same objections that discouraged their use in the autonomous event detecting package.

There was no difficulty with bandwidth for the slow scan video required nor was there difficulty with including other parameters or even the entire data stream. However if the data link were two-way, that is, if commands from shore were to be received by the Lander, the complexity would increase considerably. The utility of a one way data link was questioned since, for HEBBLE, real time information is not necessary except to monitor performance. Other oceanographic monitoring programs could better justify the development of this one way link.

Real time telemetry (two-way) was a difficult element for the workshop to deal with. The resolution of other considerations would be vastly different with telemetry than without it. The decision was finally made by vote to not use real time telemetry of data except during deployment. A provision was made to permit telemetry when another user developed the facilities and moorings without starting afresh.

Configuration

The configuration of the HEBBLE array at the start of the workshop was a Master Lander, a Vertical Array, and a Profiler at the center of the surveyed area surrounded by six outstations. The profiler, vertical array and outstation designs were consolidated into a single, tall vertical array with closely-spaced temperature sensors. Duplicates of this central configuration would then be placed at the outstation sites. Later, a supplementary set of instruments was added to the central vertical array.

The original sketch of the Master Lander showed battery pods on the legs. It was immediately recognized that these would disturb the flow and invalidate the measurements of current-induced bedform and nepheloid structures. A second sketch made by Gene Laumann went a long way toward removing these concerns. In this sketch, a central tower of electronics and batteries supports a three-arm, articulated structure with sensors suspended beneath. With three arms, duplication of sensors would permit measurements from two undisturbed positions to check the horizontal uniformity required for our one dimensional modeling. There were, however, concerns about rigidity and complexity as well as the increased number of sensors.

Detailed discussion of sensor placement on the arms created a conflict between the need for proximity for comparison and the need for undisturbed flow. A map of sensor placement was constructed but the density and number of sensors seemed to be getting out of hand. To minimize interference, the scale was increased but this caused concerns about our ability to get the Lander in and out of the water without damage. Subsequent discussions attempted to reduce the scale of the Lander.

Baseline Engineering Assumptions

--For JPL planning the following assumptions were made:

Don Collins will be the scientific liaison at JPL

Jim Irish will keep Dave Rubin informed about event triggering.

Outstations will be (in order of decreasing probability):

- (1) autonomous
- (2) talking devices
- (3) talking and listening devices

An adaptive conditional sampling algorithm will be used

Communications will be either:

- (1) no science data
- (2) status check on deployment. Could be pop-up camera, health check

Synchronization will be either:

- (1) send a time word to outstation
- (2) no synchronization

SUBCOMMITTEE REPORT ON

CURRENT SENSING

Williams (chairman), Collins, Laumann, Nowell, Orr, Smith, Weatherly,

PURPOSE OF CURRENT MEASUREMENT

The driving force for the flow in the benthic boundary layer is the current in the mixed layer. The resulting boundary layer is a turbulent flow which is affected by surface roughness, topography at intermediate scales, and the outer flow velocity. Quite close to the bottom, the turbulent fluctuations represent momentum transport to the bottom that is responsible for sediment suspension if the shear strength of the sediment is exceeded. This stress can be measured in the inertial sublayer by vector velocity sensors from which Reynolds stresses can be calculated. They permit the local shear stress to be estimated. If the flow is uniform and steady, the mean stress should be constant through the bottom few meters. Deviations from a constant Reynolds stress represent non-uniform flow in which part of the stress is carried by pressure gradients due to flow over intermediate scale bedforms or obstructions. Measurements of a Reynolds stress profile are necessary to estimate both the local stress and its representativeness. If the stress is constant, a logarithmic profile of velocity is expected which scales with the stress. Thus a simple velocity profile can replace the Reynolds stress measurement for such cases.

Geophysical flows are rarely steady and the variability of the current and shear stress is responsible for variations in sediment transport. Rare high stress events may be the dominant contribution to total sediment suspension. Whether a region is erosional or depositional may depend on only slight differences in current which in turn may be seasonal, tidal, or caused by mesoscale eddies. The purpose of a long-time series of current measurements is to statistically represent erosional events and possibly correlate them to the mean current, position of the flow on the bottom, and the cross-stream density gradients.

SENSORS REQUIRED

The measurement of mean currents in the strong flow of the WBUC is relatively easy and rotor/vane sensors should suffice for mixed layer current measurements and mean velocities near the bottom. The accuracy should be 1 cm/sec in north and east directions after vector averaging.

For Reynolds stress measurements, a vector velocity sensor is required. Acoustic current meters, electromagnetic sensors, propeller clusters, metal clad crossed hot wire sensors, and drag spheres are possible choices for this task. The acoustic current meter in the BASS configuration (Williams and Tuchko, 1977) is an optimum sensor because of low flow disturbance, sensitivity, and adaptability to a multiple axis array.

The acoustic current meter is linear through zero velocity and requires some zero point calibration such as mechanical speed indicators which exhibit an intrinsic zero point, or in situ calibration with bags over the sensors. An array of rotors at the same depths as the acoustic sensors is suggested for HEBBLE since these provide redundancy at low power for mean current profiles.

Temperature sensors at the positions of the current sensors are useful to monitor the uniformity of the mixing in the boundary layer. The temperature gradients are low and a sensitivity of 10^{-3}°C will be required to resolve much structure.

As bedforms move beneath the Reynold stress sensors, the effective height of the sensors changes. An echo sounder is needed to monitor this height. For height sensing, an accuracy of 1 cm is needed but a sensitivity of 1 mm will permit bed changes to be acoustically monitored as well.

RESPONSIBILITIES

Williams will be responsible for the BASS sensors, rotors and vane, thermistors and echo sounders for the Master Lander. Two sets will be provided to permit horizontal uniformity to be tested. Funding will be requested from ONR and, after testing, the instruments will become a permanent part of the HEBBLE Lander. Williams will provide the programs to analyze the data, and will analyze the first set from the 6-month deployment.

The rotor/vane meters for the mixed layer measurements will be the responsibility of Irish and Weatherly. There is a possibility that a thin film current meter being developed at Civil Engineering Laboratory by Kretchmer will be suitable for the current measurements in the mixed layer. We will depend on him to take the initiative in developing these sensors for that task.

CONFIGURATION

The current sensors will be in a vertical array on the Master Lander. The acoustic current meter must be 5 diameters from any structure and 100 diameters from upstream obstructions. Two or three sets of

current meter arrays will go on the Master Lander to verify lateral homogeneity. An echo sounder will be placed next to the acoustic current meter array.

POWER, ETC.

Power for the rotor-vane sensors is low and can be neglected compared to the acoustic current meters. These presently draw 200 ma from a 5 v supply, and 120 ma from an 18 v supply (the latter to provide 12 v, -1.2 v, and +500 v from a converter) for the period it is on. A maximum of 3 Hz sampling should be adequate and the required on-time for the "power hungry" components is only about 16 milliseconds per sample. While this is a duty cycle of only 1/2%, savings in power of better than a factor of 100 may be difficult. However, even lower duty cycles are possible. Peak currents can exceed 1 amp from TTL switching.

Data rates are 432 bits/sample for a 4 sensor array of acoustic current meters with thermistors before averaging. A 5-minute average would require 444 bits of processed data. All of this should be stored. If two acoustic arrays are used, this would double. The rotors and vanes would add 96 bits/ 5-minute sample.

PROGRAM

Data will be taken at a constant rate for in situ processing and can be used to generate an event trigger. In the case of an event, it may be desirable to sample at a higher rate but this could be done from the rotors.

SUBCOMMITTEE REPORT ON

CONDITIONAL SAMPLING

Irish (chairman), Brunstein, Correll, Jaffe, Orr, Rubin, Wimbush, Zaneveld

PURPOSE

Due to the highly intermittent behavior of sediment transport in the deep ocean boundary layer, some form of conditional sampling is required for the HEBBLE program. It is impossible to record at a high enough rate (1 Hz) to resolve the fluctuations for the 6-month duration of the experiment and store the results on existing recorders. Also, the energetic events which move the sediment occur only during occasional high energy bursts. Therefore, an event detection scheme is required which will sample the event at a high rate required to resolve the process, and then go back to a low sample rate when the event is complete. The conditional sampling required by HEBBLE is more than just event detection, it also includes (1) preprocessing, (2) data compression and (3) adaptive sampling.

Preprocessing: Signals sampled at the low sample rate may be disguised unless proper low pass filtering is done. By averaging the currents (or other quantities sensed) over the sample interval, adequate suppression of high frequencies is obtained. Also with preprocessing, the vector current velocity components can be calculated at the high sample rate, and these components averaged to form a proper velocity average. Further computations can be made, such as Reynolds stress or velocity-nepheloid concentration correlations and recorded. The preprocessing allows proper averaging of quantities to be made in relation to the low sampling rate without disguising effects.

Data compression: Conditional sampling allows one to ignore data that is not of interest. Thus only the data of interest is recorded leaving out the sections where little is happening.

Adaptive sampling: Adaptive sampling allows the recording system to change the conditional sampling parameters during the experiment. The critical values for event detection could be modified according to magnetic tape and battery power usage; the sample rate changed depending on level of signal; malfunctioning sensors eliminated from the event-detecting criteria.

INPUTS FOR CONDITIONAL SAMPLING

On the Master Lander a group of sensors are available for inputs to and control by conditional sampling. These are:

1. Current meters
 - A. BASS - 3-axis acoustic velocity sensors
 - B. Rotor current meters with vanes
2. Nephelometers
 - A. OSU transmissometer
 - B. Lamont-Doherty nephelometer
3. ABSS - acoustic backscattering sensor, both up and down
4. Bottom echo sounder (acoustic disturbance detector)
5. Images from TV camera

SUGGESTED SAMPLING

In order to define an adequate sampling program for HEBBLE, some detailed knowledge of the signals must be known. At present, (before the 3-day experiments and pilot experiment) we do not have adequate data to define a conditional sampling scheme. However, the basic approach illustrated in the examples will be further refined into a detailed sampling program as we obtain more data.

Low frequency sampling: In addition to any conditional sampling, all the sensors will be recorded at a fixed low frequency rate. A sample interval of 5 minutes was selected since it relates to the minimum averaging time for BASS to obtain a good estimate of Reynolds Stress. The data, which is sampled at a basic frequency of 1 Hz and averaged to 5 minute values, would be recorded on a JPL tape recorder having a 10^9 bit capacity. Table 1 gives the bits recorded from each sensor during a scan of all sensors. For the 6-month experiment this would amount to 2.4×10^8 bits, or 1/4 of the tape capacity. The remaining tape can be used for high frequency event recording. It should be noted that at a 2 1/2 minute sample rate, one half the tape would be available for event data. Also a scheme which samples some of the sensors at different rates could be designed; for example, the nephelometers could be sampled at 1 minute intervals and all the other sensors at 5-minute intervals.

Event detection and adaptive sampling: When an event is detected, some action is taken, such as increasing the sample rate. However, by the time that an event is triggered, the beginning of that event has

passed. To obtain this data, a recirculating memory is required which will store the last half hour of data of the 1 Hz rate, and record this on tape when an event is triggered to sample the start of the event.

Since we cannot at this time define the event detection scheme required for HEBBLE, some examples are given below which indicate the required capabilities of the system, and show what might be accomplished by conditional sampling.

Examples of possible event detectors:

1. An event is defined by a change in value, such as an increase in current velocity or a decrease in optical transmissometer reading. If the signals are noisy some smoothing may have to be done.
2. An event is defined when a value exceeds some preset level, such as the critical value for sediment erosion.
3. A non-event could be defined when nothing is happening, i.e. when the current is below 10 cm/sec and the transmissivity is above 60%. The recording rate could be slowed down considerably: once per hour could save more tape.
4. The end of an event could be defined by the signal dropping below the detection level originally specified. Also a different signal level could be selected to give the detector some hysteresis.
5. The end of an event could be defined by limiting the length of a single event to save tape space.

Examples of possible adaptive sampling schemes:

1. To avoid filling up the tape with one kind of event, the adaptive sampling would keep track of events and not allow more than a certain number within a given time. An example might be an advective event of high nephelometer and low velocity value which occurs too closely behind another event of the same kind. The second event would be ignored, but the start time and duration could be recorded to give event statistics.
2. The experiment can become "smart" and set its own critical values: i.e., take the mean and variance of the entire record up to the present. Set the critical value equal to the mean plus two standard deviations. By the end of the experiment, a statistically good value will be determined and used to detect events.

3. Checks would be made to see if the data was noise by checking against large first differences and by comparing with preset acceptable geophysical levels.
4. Compare high values from one sensor with other sensors to determine possible sensor malfunction; if so, eliminate the use of that particular sensor in determining an event.

Examples of actions in response to an event trigger:

An action may be initiated by a preselected logical combination of event triggers, and different combinations of events can be required to trigger different actions.

1. Sample all sensors at the high rate when both velocity and nephelometer levels are above critical.
2. Record time and duration of an event, as well as levels.
3. Trigger the camera when the current level is high. Increase the sample rate, but stop when a nephelometer event is determined and the suspended particles block the image of the sea floor.
4. Increase the sample rate by steps as the current level increases.
5. Shut the cameras off when the nephelometer level is high, but if it should suddenly drop, take a picture.

Other events, adaptive schemes and actions could be envisioned, but with the capability to do the above conditional sampling built into the Master Lander, software can be developed and modified as our knowledge increases.

Responsibility for conditional sampling is shared by J. Irish and D. Rubin.

It should be noted that all the sensors will be sampled at a 1 Hz rate in the proposed sampling scheme. These values are stored in the recycling buffer. The conditional sampling circuit would then act on these 1 Hz values, either detecting an event and just transferring the values to tape, or averaging, calculating and other preprocessing before writing the data on tape. All computations would be done in the Master Lander.

SUBCOMMITTEE REPORT ON
THE BOTTOM MIXED LAYER

Williams (chairman), Irish, Laumann, Weatherly, Wimbush

PURPOSE OF MEASUREMENT

The ultimate goal of the HEBBLE Program is to understand the dynamics of the benthic boundary layer flow and its interaction with the sea bed. The objective of the vertical arrays is to provide data for the former; the Master Lander, for the latter. Most physical oceanographers regard the bottom mixed layer (BML) as the region which encompasses the benthic boundary layer (BBL), i.e. the BBL is believed to occupy a significant fraction or all of the BML. Thus an understanding of the BML (e.g. what determines its thickness and spatial and temporal variability in a high energy region) is essential to the goals of HEBBLE.

In order to realize this objective it is necessary to obtain velocity and density data above the BML in the so-called free stream or geostrophic region not only at the site of interest (the Master Lander Site) but at nearby sites as well in order to assess the relative roles of local and horizontally advected processes in the formation and maintenance of the BML.

The types of measurements required are: (1) a) velocity profiles throughout and above the BML of sufficient resolution to delineate the velocity (N.B. speed and direction) profile of the BML; b) the free stream/geostrophic velocity and its vertical shear and; c) the logarithmic layer, and 2) vertical density profiles (minimum T, preferable T and S or C) throughout and above the BML to delineate the BML, to determine when it has vertical structure, and to determine the stratification in the free-stream region. As part of determining the interaction of the BBL with the sea bed and the contribution of suspended particulate matter on density structure of the BML profile measurements in and above the BML of suspended material are also required.

SENSORS AND INSTRUMENTS REQUIRED

It is our view that existing sensors are more than adequate to obtain data of sufficient quality for the above purposes. It is also our view that while new devices may be desirable for making these measurements, (e.g. a deep-sea cyclesonde) existing instrumentation, with either little or no modifications and re-calibration, is adequate. This

simplification arises because we are interested in obtaining mean quantities as opposed to the turbulent microstructure and these observations are to be made in a strong current regime removed from surface wave activity. Geodyne Model 100 current meters and VACM's have proved to be adequate tools for making velocity measurements in the BBL in another deep, high energy flow: the Florida Current.

Velocity measurements are to be made with modified Geodyne Model 100 current meters. To delineate the logarithmic layer (expected thickness approximately 5m), three current meters will be placed so their sensors are 0.5m, 2.5m and 4.5m above the bottom. Temperature measurements are to be made with thermistors and recorded by the current meter data loggers. The thermistors have sensitivity of $.001^{\circ}\text{C}$ and will be intercalibrated at the NAVOCEANO Calibration Laboratory, NSTL, Mississippi, so that relative temperature differences of $.003^{\circ}$ can be resolved. The sensitivity of the thermistors is sufficient to determine when they are in a well-mixed layer; after intercalibration vertical and horizontal gradients in and above the BML can be estimated. Nephelometers and sediment traps are to be used to detect suspended particulate matter.

POSITIONING AND SAMPLING OF SENSORS AND INSTRUMENTS

Our present lack of knowledge about the BML of the Western Boundary Undercurrent prevents our specifying the precise number and heights above the bottom of the required sensors needed on each array. Four arrays are required: one at the main lander site, two cross-stream (one up slope, one down slope of the main lander site) and the fourth upstream. The outstations are to be about 10-20 km from the Master Lander site and will not be as heavily instrumented as the main vertical array. If h is the BML thickness and the amplitude of its variability, 10 current meter/thermistors will be placed nominally at .5m, 2.5m, 4.5m, 10m, $h/3$, $2h/3$, $h/2$, $h + /2$, $2h$ and $3h$ at the main site. Approximately 15 current meters will be available for the outstations and normally 10 thermistors are to be strung on each outstation mooring. Bottom pressure is to be measured at each vertical array.

A modular recording system with independent current meter modules will be employed. A digital tape recorder, designed for such applications, is to be used. Thus, at the outstations the current meters can be used as data loggers for mini-thermistor chains, conductivity and pressure probes as needed.

Ekman veering (i.e. mean current direction changes in the BBL) of the Florida Current BBL can be inferred from measurements by Geodyne Model 100 current meters and VACM's equally well. The results of Weatherly and Wimbush (1979) indicate that the BBL of the Western Boundary Undercurrent is more steady in direction than the Florida

Current BBL. It is our contention that an Aanderaa Current meter sampling scheme, (i.e. recording mean speed and one instantaneous direction every sample interval) is adequate for determining reliable estimates of the mean veering in the BML. The currents will be sampled in this fashion every 5 minutes. Should future developments require a different sampling scheme (e.g. burst sampling or some form of vector averaging) the current meters can be so modified by the addition of suitable cards.

Ten nephelometers and sediment traps are to be mounted on the central vertical array at heights comparable to the current meters. At the outstations, one nephelometer at nominally 10m is to be deployed.

HYDROGRAPHY

Cross-stream CTDN transects encompassing the outstations are to be made after the installation and before the recovery of the vertical arrays. The objectives of these transects are: (a) to determine the slope of the isopycnal surfaces relative to the bottom in the lowest 300m; (b) to give more detailed profiles in and above the mixed layer than available from fixed level recorders, and (c) to give ground truth temperature (conductivity) data for intercomparison of the fixed level temperature (conductivity) measurements. These objectives are critical to the modeling efforts of HEBBLE, the determination of the vertical and horizontal spacing of the fixed level sensors, and intercomparison of temperature (conductivity) measurements. It is necessary that the transects made after deployment be made at least 12 hours after deployment to permit the temperature electronics to reach equilibrium.

SUBCOMMITTEE REPORT ON

IMAGING

Wimbush, Biscaye, Hollister, Jaffe, Laumann, Nowell

PURPOSE

In rapidly decreasing order of importance, the purposes of the imaging systems are:

1. Recording hydrodynamic disturbance of the sea bed (e.g. formation, migration and decay of bedforms) with resolution on the order of one mm in the vertical and a fraction of a mm in the horizontal.
2. Recording biological activity, especially biological disturbance of the sea bed.
3. Exterior monitoring of the apparatus, e.g. sediment penetration of the apparatus legs, fouling of rotors.
4. Recording fluctuations of turbidity in the meter-thick layer of water above the sediment (this would rank much higher in importance if the turbidity were not already recorded more sensitively and precisely by other devices).

SENSORS REQUIRED

The camera system combination to be used depends on the mode of system design as specified in the following table:

CAMERA	CHARACTERISTICS	OBJECT SCALE	FRAME SIZE	RES. (lines/mm)	APPROX. FRAME RATE	A	B	C
1	Pop-up film camera surfaces 1 day after launch	1 m	35 mm	500	1/hr.	x	x	x
2	Time-lapse movie camera with constant frame rate	1 m	16 mm	1000	1/hr	x	x	x
3	Event triggered movie camera	1 m	35 mm	500	12/hr max	x	x	
4	Event triggered narrow-area coverage movie camera	10 cm	35 mm	500	12/hr max	x	x	
5	Wide-area coverage time-lapse movie camera (oblique)	10 m	35 mm	500	1/hr	x	x	x
6	Stereo-pair film cameras	1 m	35 mm	500	1/hr		x	x

Note: #6's purpose is the determination of bottom relief which will be done using standard photogrammetric techniques.

MODE:

- A = Adaptive burst sampling on events
- B = Burst sampling on events
- C = Constant sampling

RESPONSIBILITY FOR SENSORS

<u>Sensor</u>	<u>P.I.</u>	<u>Funding</u>
1	Biscaye	ONR
2	Wimbush	ONR
3	Biscaye	ONR
4	Biscaye	ONR
5	Biscaye	ONR
6	Hollister	ONR

CONFIGURATION OF SENSORS ON VEHICLES

All imaging systems will be on the Master Lander.

Cameras #1, 2, 3, 4, 6 will look vertically downward at the sea bed from an elevation between 1 m and 2 m. (If they are lower than this they may disturb the bottom in their field of view, if higher than this they may suffer excessive loss of contrast from suspended particles.) At least 25% of the field of view of any one of these cameras will be common to all of them.¹ This "common patch" must be clear of any significant disturbance due to the apparatus.

As many as possible of the Master Lander's sensors should be in the field of view of the #5 camera.

The principal strobe light(s) should be at approximately 30 cm elevation and aimed obliquely at the patch of sea bed to be imaged. It might conveniently be attached to one of the lander's legs. If the light is well baffled, this arrangement will minimize contrast loss from particle back-scattering and will emphasize any bottom relief.

¹ Except that the 10 cm field of view of camera #4 will be wholly within the 25x25cm common patch.

POWER, DATA RATES, DATA STORAGE, FORMAT

For data rates and formats see table.

Power requirements and "data storage" requirements² are given in the following table, together with information on component dimensions:

<u>Camera #</u>	<u>Volts</u>	<u>Milliamps</u>	<u>Duration sec.</u>	<u>Capacity</u>	<u>Diameter cm.</u>	<u>Length cm.</u>
1				100 frames	11	40
2	6.75	10	15	4000 frames*	17	40
3	24	5	50	4000 frames**	18	35
4	24	5	50	4000 frames**	18	35
5	24	5	50	4000 frames**	18	35
6	24	5	50	6400 frames*** per camera	21	75

* 100' reel standard base color film

** 250' reel thin base black and white film

*** 800' reel thin base black and white film

PROGRAM OF DATA TAKING

Cameras #1, 2, 5, will have constant frame rates.

Cameras #3 and 4 will not take any pictures until an "event" is signalled. The most likely source of an autonomous event signal would be near-bottom current speed.

² These requirements will be handled by the camera sub-system.

SUBCOMMITTEE REPORT ON
SUSPENDED PARTICULATE MATTER (SPM)

Biscaye, Bartz, Carder, McCave, Orr, Zaneveld

PURPOSE OF MEASUREMENT

In the context of other measurements to be made during the 6-month experiment (current velocity, direction, Reynolds Stress, T, S, etc.) the objectives are:

1. to measure quantities of SPM as a function of time, height above bottom near the BBL and over a relatively small horizontal field;
2. to measure the physical characteristics (primarily settling velocity and size) of SPM as a function of time and, perhaps, as a function of height near bottom;
3. to collect samples of SPM to measure their physical, mineralogical, chemical and natural radioisotopic characteristics as a function of time and height above bottom within the BBL;

in order to understand the relationship between quantities and character of SPM and the causitive factors for its being in and falling out of suspension.

SENSORS REQUIRED: STATUS AND RESPONSIBILITY

Because the possible available sensors have not been tested together, we do not know the degree to which they do or do not measure the same thing concerning SPM. Considerable apparent redundancy is therefore necessary at this time. This may or may not be reduced by the time of a 6-month experiment, but none can a priori be eliminated now. The instruments are listed according to the three separate objectives listed above.

1. Quantities of SPM

- a. Beam transmissometers (c-meter). At this time both the 100 cm and 25 cm path length are feasible but 100 cm seems more likely from the viewpoint of required sensitivity. These instruments are operational for deep-ocean work and are the responsibility of Zaneveld and Bartz at OSU.

b. Acoustic backscatter system (ABSS). This instrument which has both an upward and a downward-looking component is operational for shallow work but has not yet been used in the deep sea and is the responsibility of Orr at WHOI.

c. L-DGO-Thorndike nephelometer. This instrument, which is a forward-scattering nephelometer, is, in its present configuration, the white-light, photographic-detector instrument which has been used for over a decade in the deep sea. A program to modify just the detector system to a digitally-recording mode is being undertaken and is anticipated to be operational before a 6-month experiment. This instrument is the responsibility of Biscaye and Gardner at L-DGO.

2. Physical Characteristics of SPM

The only sensor presently envisioned for measuring settling velocities and particle size of SPM is under development. It will consist of a settling tube which will be vanned to have near-bottom water flowing through it but capable of being closed off at top and bottom. A beam transmissometer mounted in the wall of the tube and looking across the tube will measure the change in SPM in the tube as a function of time from which the settling velocity distribution may be calculated.

A laser-transmission-holographic system also mounted to look across the tube will measure the size-frequency distribution of the larger particles of settling SPM. This system also yields information on particle shape and can yield calculated particle densities. The tube and beam transmissometer are the responsibility of Zaneveld and Bartz of OSU and the laser-holographic system is the responsibility of Carder at University of South Florida.

3. SPM Samples for Physical, Chemical, etc. Characteristics

Cylindrical sediment traps (12 in. dia; 36 in. long) capable of collecting particles in a time series will provide samples of material on which various analyses may be run. The sample is divided into a maximum of eight aliquots by means of a device which rotates a different sample container under a funnel mounted in the bottom of the trap. These traps are similar to those used previously by Gardner and will be the responsibility of Gardner and Biscaye at L-DGO.

CONFIGURATION OF SENSORS ON VEHICLES

Because the exact number and nature of each bottom package is not known, configuration and number of sensors is uncertain. Whereas a design for the Master Lander, for example, may be such that all measurements could be made by a single sensor or single array of sensors of each type without interfering with any other sensor, some degree of redundancy is nonetheless desirable both for the scientific and technological integrity of the experiment. The numbers listed below are the minimum for each type of package.

1. Master Lander

- a. Vertical array of four 100 cm path-length c-meters (from the bottom up to 2 mab (meters above bottom)).
- b. A minimum of one up-looking and one down-looking ABSS at approximately 1 mab.
- c. Minimum of our L-DGO-Thorndike nephelometer at approximately 1 or 2 mab (at same height as one of c-meters). It may be desirable to add a standard photographic as well as a digital nephelometer.
- d. One and possibly two settling tubes for settling velocity/particle size measurements (c-meter; laser-holograph) mounted at perhaps 50 cm and 2 mab.

2. Vertical Array (Inner-Outstation)

- a. At approximately the same heights as a dozen current meters, 12 c-meters mounted from near bottom up to approximately 300 mab. Some of the adjacent current meters will be the dozen mounted logarithmically by George Weatherly in the bottom 40m, but additional current meters will have to be added up to 700 mab and will be in a linear array.

At approximately the same levels (mab) as the current meters and c-meters will be a dozen time-series sediment traps.

3. Outstations (other)

At present there appear to be plans for 12 c-meters spaced up to 40 mab at each of the 4 outstations.

POWER, DATA RATES, STORAGE, FORMAT

These data have been or are being specified by the PI's in preliminary outlines to JPL.

PROGRAM OF DATA TAKING

This has been only partly specified and is still subject in part to the uncertainties of plans with regard to event-triggered data taking.

SUBCOMMITTEE REPORT ON
SEDIMENT PROPERTY DETERMINATION AND LABORATORY
EXPERIMENTAL PROGRAM

McCave (chairman), Carder, Collins, Fanning, Hollister, Jaffe, Laumann, Silva

PURPOSE

We need to know properties of the bed at the lander site to assist in interpretation of data taken in this experiment and to assess longer term aspects of erosion and deposition and of organic activity which might influence them. Most of the sediment properties will be determined on samples from box cores and from the URI large diameter gravity core. Only vane shear strength will be determined by a sensor on the Master Lander. The laboratory experimental program is designed to increase our understanding of the behavior of bed materials under fluid stress--critical conditions and rates of erosion--and to understand features of the turbulent flow over replicas of the bed under controlled conditions.

SAMPLING FOR SEDIMENT PROPERTIES

Samples will be taken during site-survey cruises and during deployment cruises using a Reineck-type box corer of modern design, preferably with damped entry to minimize bed disturbance. Most of the geotechnical determinations will be made on samples taken at the same time with the URI large diameter (4") gravity corer. Large-volume cold storage facilities will be needed on the ship for box cores.

PROPERTIES TO BE DETERMINED ON CORES

The workers and laboratories with primary interest and responsibility are named.

1. Geotechnical properties: water content, Atterberg limits, shear strength profile, surface shear strength, triaxial compression and consolidation tests (Silva/URI)
2. Acoustic compressional and shear wave velocities (Silva/Baldwin/URI)
3. Sediment size and texture and microstructure by SEM (Tucholke/Hollister/McCave/WHOI; Silva/URI; Yingst/Yale)
4. Microfossil content and stratigraphy (Hollister/McCave/Tucholke/WHOI)

5. Clays, mineralogy, carbonate and opal content (Hollister/Tucholke/McCave/WHOI)
6. Visual and x-ray determination of sedimentary structures (Hollister/Tucholke/McCave/WHOI)
7. ^{14}C (and $^{230}\text{Th}_{\text{xs}}$?) for age and assessment of bioturbation (poss. Biscaye/LDGO; Yingst/Yale)
8. Cation exchange capacity, organic carbon, possible pore-water components (Hollister/McCave/WHOI with advice from F. Sayles)
9. Macrofaunal content (Jumars/UW)
10. Surface mucus (mucopolysaccharide) determination and possibly ATP for bacterial activity (Yingst/Yale).

A problem which remains in much of this work is determination of the properties of the upper 100 micro-meters of the bed inasmuch as it is very difficult to be sure that this layer has been completely preserved in a box core. Possibly some in situ acoustic holographic techniques will be able to provide information on particle characteristics.

OPERATIONS TO BE PERFORMED ON THE LANDER

1. Surface shear strength and the vane shear strength profile are to be determined at the beginning and end of the deployment. Preliminary details of the instrument are given in the Appendix to this report.
2. A short (1.5 m, 0.15 m diameter) core is desirable from the Lander site. This could be taken at the beginning and returned to the surface immediately or it could be taken during recovery. The latter is preferable to minimize bed disturbance at the site.

LABORATORY EXPERIMENTS

Erodibility. A sampler for recovering an undisturbed piece of the bed in a container designed to fit into a newly constructed water tunnel is available at URI. The water tunnel has equipment for measuring pressure gradients, velocity gradients and suspended sediment concentration by transmissometry. In addition, the total stress on the sediment can be measured by strain gauges and the water can be cooled to 3°C . Critical erosion experiments will be conducted in this apparatus at URI by a group in Silva's lab, principally J. Heavers.

Back-up experiments may also be conducted in J.B. Southard's salt water flume at MIT, using samples from box cores. As a part of the

Shelf Sediment Dynamics Program Southard will also construct a flume at Washington in which organisms can be cultured to examine their effect on erodibility. Some arrangement may be possible if examination of sediment properties suggests similar experiments might be useful on deep-sea sediments.

TURBULENCE OVER A NATURAL ROUGH BOUNDARY

Surface replicas will be made of the upper surface of box cores. The technique will probably be to inject a polymer into the supernatant water as soon as possible after the core is taken, possibly during the pull-out of the core from the bed. This surface mold will be used to make replicas which can be inserted in a flume instrumented for turbulence measurements. At present there are two groups interested in these measurements, Gust at MIT with Paola at WHOI, and Nowell and Smith at UW.

SEAFLUME

Though not a laboratory measurement, Southard's Mark II Seaflume will be used to determine erodibility in situ (Young and Southard, G.S.A. Bull., 1978). Suggested additions to the instrument are (a) an interface camera mounted in the side of the flume; (b) a transmissometer to measure the onset of erosion better and; (c) a laser holography system to examine the nature of the eroded particles.

APPENDIX

SEDIMENT PROPERTIES INSTRUMENTS

1. CORER--Instrument summary for Master Lander

P.I.--Armand Silva, URI

Objectives: Obtain core sample of upper 1 meter of sediment for laboratory analyses.

Measured Phenomenon--physical sample
Range--N.A.
Prec.--N.A.
Freq.--once at end of deployment

Location: As close to test bed as possible but not adjacent to foundation pads.

Dimensions: 15 cm diam x 1.5 m length

Weight in air: 150 lbs.

Power Requirements: Minimal, triggering of hydrostatic corer

Data Processing: N.A.

Command Requirements: Triggering of hydrostatic corer at end of experiment.

2. VANE SHEAR DEVICE--Instrument Summary for Master Lander

P.I.: Armand Silva (URI)

Objectives: Determine vertical profile of undrained sediment shear strength at the test site.

Measured Phenomenon: Measures undrained shear strength at described locations starting at the surface to a depth of 20-30 cm.

Measurement Range: Sediment shear strength of 0-100 gm/cm²

Measurement Precision: 0.5 gm/cm² shear strength

Normal Measurement Frequency: At end of experiment, series of eight measurement locations at each test site, two test sites recommended.

During Event: N.A.

Location: As close to bottom test bed as possible. Can be stored at considerable distance above bottom until initiation of measurements.

Dimensions: Pressure housing 15 cm x 15 cm with 40 cm shaft projection, rock mounted for vertical positioning.

Weight in air: 100 lbs.

Power Requirements: 150 kg-cm-sec for each measurement, 1200 kg-cm-sec for each test site. Approximately 10 volt constant voltage supply.

Data Processing Requirements: For each measurement, two readings per second for approximately 5 minutes, 600 data points of torque output and degree of twist.

Command Requirements: Commands for sequential positioning of vane and initiation of each measurement operation.

TABLE I

SENSOR	MEASUREMENT	SENSOR RESPONSIBILITY	SAMPLING	SENSORS PER ARRAY	NUMBER OF ARRAYS	BITS PER SENSOR	TOTAL BITS PER SAMPLE
BASS	3-components velocity	Williams	9 averages per sensor	4	2	12	864
ROTOR/VANE	2 components of velocity	Williams	2 averages per sensor	4	2	12	192
THERMISTORS	Temperature	Williams	Average	4	1	12	48
C-METER	Optical Transmission	Zaneveld	Instantaneous Sample	4	1	12	48
ABSS	Up and down Acoustic Backscattering	Orr	Instantaneous	2	1	1,524	3,048
FIXED CTD	Temperature Conductivity Pressure	Irish	Averages	3	1	16	48
NEPHELOMETER	Suspended Sediment	Biscaye	Instantaneous Sample	1	1	?	<128*
BOTTOM ECHO SOUNDER	Distance to Bottom	Williams	Instantaneous Sample	1	2	12	24
DIAGNOSTICS	Event times, time of camera triggers, tilt, direction, sediment trap triggers, etc.	JPL	---	-	-	--	100
						TOTAL	4,500 bits/sample

*This number is assumed since equipment is not yet designed for digitization.

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<p>Woods Hole Oceanographic Institution WHOI-79-71</p> <p>THE HERBLE II REPORT - PROCEEDINGS OF THE SECOND ANNUAL WORKSHOP ON THE HIGH ENERGY BENTHIC BOUNDARY LAYER EXPERIMENT HELD AT THE KEYSTONE CENTER FOR CONTINUING EDUCATION BY A. J. WILLIAMS III, C. D. HOLLISTER AND R. S. CHANDLER. 31 PAGES. August 1979. Prepared for the Office of Naval Research under Contract N00014-74-C-0262; NR 083-004.</p> <p>A meeting was held March 19-24, 1979, to produce an engineering plan for the High Energy Benthic Boundary Layer Experiment. This document outlines the principal conclusions of that meeting with a synopsis of the engineering requirements and with the reports of sub-committees on current sensing, conditional sampling, bottom sized layer measurement, imaging, suspended particulate matter and sediment property and laboratory experimental programs. In each report, details of sensors and properties to be determined are given.</p>	<p>1. Benthic boundary layer</p> <p>2. Bedforms</p> <p>3. Current measurement</p> <p>I. Williams, A. J., III</p> <p>II. Hollister, C. D.</p> <p>III. Chandler, R. S.</p> <p>IV. N00014-74-C-0262; NR 083-004</p> <p>This card is UNCLASSIFIED</p>	<p>Woods Hole Oceanographic Institution WHOI-79-71</p> <p>THE HERBLE II REPORT - PROCEEDINGS OF THE SECOND ANNUAL WORKSHOP ON THE HIGH ENERGY BENTHIC BOUNDARY LAYER EXPERIMENT HELD AT THE KEYSTONE CENTER FOR CONTINUING EDUCATION BY A. J. WILLIAMS III, C. D. HOLLISTER AND R. S. CHANDLER. 31 PAGES. August 1979. Prepared for the Office of Naval Research under Contract N00014-74-C-0262; NR 083-004.</p> <p>A meeting was held March 19-24, 1979, to produce an engineering plan for the High Energy Benthic Boundary Layer Experiment. This document outlines the principal conclusions of that meeting with a synopsis of the engineering requirements and with the reports of sub-committees on current sensing, conditional sampling, bottom sized layer measurement, imaging, suspended particulate matter and sediment property and laboratory experimental programs. In each report, details of sensors and properties to be determined are given.</p>	<p>1. Benthic boundary layer</p> <p>2. Bedforms</p> <p>3. Current measurement</p> <p>I. Williams, A. J., III</p> <p>II. Hollister, C. D.</p> <p>III. Chandler, R. S.</p> <p>IV. N00014-74-C-0262; NR 083-004</p> <p>This card is UNCLASSIFIED</p>
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