



*Measurements*

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**Meteorological and Oceanographic Data  
during the ASREX III Field Experiment:  
Cruise and Data Report**

by

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Woods Hole Oceanographic Institution  
Woods Hole, Massachusetts 02543

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**Technical Report**

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## Abstract

The Third Acoustic Surface Reverberation Experiment (ASREX III) took place from December 1993 to March 1994 at Site L (34°N, 70°W) in the mid-Atlantic. As part of this experiment, two moorings were deployed to measure the environmental background. A meteorological and oceanographic mooring was deployed to characterize the surface wind stress, buoyancy flux, and the current and temperature structure over the top 500 meters. A Seatex Wavescan™ buoy was deployed to characterize the directional wave spectrum. This report presents results from these moorings. Wind speeds up to 25 m/s were seen, with significant heat losses (up to 1050 W/m<sup>2</sup>) when cold continental air moved out over the warm Atlantic. The wave heights ranged up to 8 m, with significant wave heights of several meters persisting for relatively long periods. Wave height and period, nondirectional spectra, directional spectra and a typology of wave events are presented and related to surface forcing.



## Table of Contents

	Page No.
Abstract.....	i
List of Figures .....	v
List of Tables .....	vi
1. Introduction .....	1
2. Mooring information .....	1
2.1 Introduction.....	1
2.2 SIO Soundspeed Mooring .....	5
2.3 The Seatex Mooring .....	6
2.4 The UOP Discus Mooring .....	6
2.5 The Miami Acoustics Mooring .....	6
2.6 The ELSI B Mooring .....	12
3. Data Presentation .....	22
3.1 Meteorology .....	22
3.2 Temperature Structure .....	47
3.3 Current Velocities .....	72
3.4 Wave Data .....	89
Acknowledgments .....	90
References .....	91
Appendix 1: Cruise Participants .....	231
Appendix 2: Cruise Chronology .....	232
Appendix 3: ASREX Antifouling Tests .....	236
Appendix 4: Matlab code for calculating wave directional spectra .....	242



## List of Figures

Page No.

2.1	Map of ASREX Site .....	2
2.2	Map of the moorings deployed during ASREX .....	4
2.3	Diagram of SIO Soundspeed mooring .....	15
2.4	Diagram of Seatex mooring .....	16
2.5	Diagram of Discus mooring .....	17
2.6	Diagram of Miami Acoustics mooring .....	18
2.7	Diagram of ELSI B mooring .....	19
2.8	Argos positions of the Discus mooring .....	20
2.9	Argos positions of the Seatex mooring .....	21
3.1.1–7	Meteorology Time Series .....	23–29
3.1.8–14	Heat Flux Time Series .....	32–38
3.1.15–21	Wind Stress Time Series .....	39–45
3.1.22	Autospectra of Meteorological Variables .....	46
3.2.1	Contour Plot of Temperature .....	48
3.2.2–23	Temperature Time Series and Spectra .....	49–70
3.2.24	Seacat Temperature Profiles .....	71
3.3.1–6	Subsurface Velocity Vectors (Low-Frequency) .....	73–78
3.3.7–8	Progressive Vector Diagrams .....	79–80
3.3.9–16	Velocity Time Series and Spectra .....	81–88
3.4.1–3	Nondirectional wave parameters .....	92–94
3.4.4–6	Evolution of wave field vs. Frequency .....	95–97
3.4.7–9	Evolution of wave direction and wind direction .....	98–100
3.4.10–139	Directional wave spectra .....	101–230
A.3.1	Discus hull and bridle profile .....	237
A.3.2	Discus hull antifouling diagram .....	238
A.3.3	Instrument antifouling diagram .....	239

## List of Tables

	Page No.
2.1 Mooring information .....	3
2.2 SIO Soundspeed mooring instrumentation information .....	7
2.3 Seatex instrumentation information .....	8
2.4 Discus instrumentation information .....	8
2.5 Miami Acoustics Mooring instrumentation information .....	9
2.6 Miami acoustics package specifications .....	10
2.7 ELSI B instrumentation information .....	14
3.1.1 Schematic of VAWR sensor averaging periods .....	30
3.1.2 Meteorological sensor specifications, VAWR .....	30



## 1. Introduction

The Third Acoustic Surface Reverberation Experiment, (ASREX III) was designed to study processes causing degraded acoustic transmission in high sea states (see McDaniel, 1993, for a review of the state of the scientific understanding before this experiment). The experiment took place in late 1993 and early 1994 at Site L (34N 70W) over the Hatteras Abyssal Plain. In support of this experiment, a total of five moorings were deployed. Section 2 of this report describes the mooring array in order to provide the overall context for the experiment. Section 3 then describes the environmental background during the experiment, including the temperature, salinity, and current structure in the upper 500 m, surface meteorology, and wave conditions. The bulk of this data is taken from two moorings, a meteorological/oceanographic mooring and a wave mooring deployed by the Upper Ocean Processes (UOP) group at the Woods Hole Oceanographic Institution.

## 2. Mooring Information

### 2.1 Introduction

The moorings were deployed from the R/V *Knorr* of Woods Hole Oceanographic Institution, sailing from Woods Hole on 8 December 1993. The moorings were recovered by the R/V *Edwin Link* of Harbor Branch Oceanographic Institution, sailing from Jacksonville on 18 March 1994. Figure 2.1 shows a bathymetric map of the area surrounding the experiment site. Recovery and deployment were directed by John Kemp of WHOI's Ocean Acoustics Laboratory (OAL). A list of cruise participants appears in Appendix 1 and the chronology of the cruises is described in Appendix 2.

A total of five moorings were deployed during ASREX III. These were:

1. A near-surface soundspeed mooring, instrumented by Dr. W. K. Melville's group at Scripps Institution of Oceanography (SIO).
2. A Seatex wave mooring instrumented by the UOP and OAL groups at WHOI.
3. A meteorological/oceanographic discus mooring instrumented by the UOP group at WHOI.
4. An acoustics mooring instrumented by Dr. H. DeFerrari's group at the University of Miami and Dr. D. M. Farmer's group at the Institute for Ocean Sciences (IOS), Sidney, BC, Canada.
5. An ELSI B sonar mooring instrumented by D. Farmer's group at IOS.

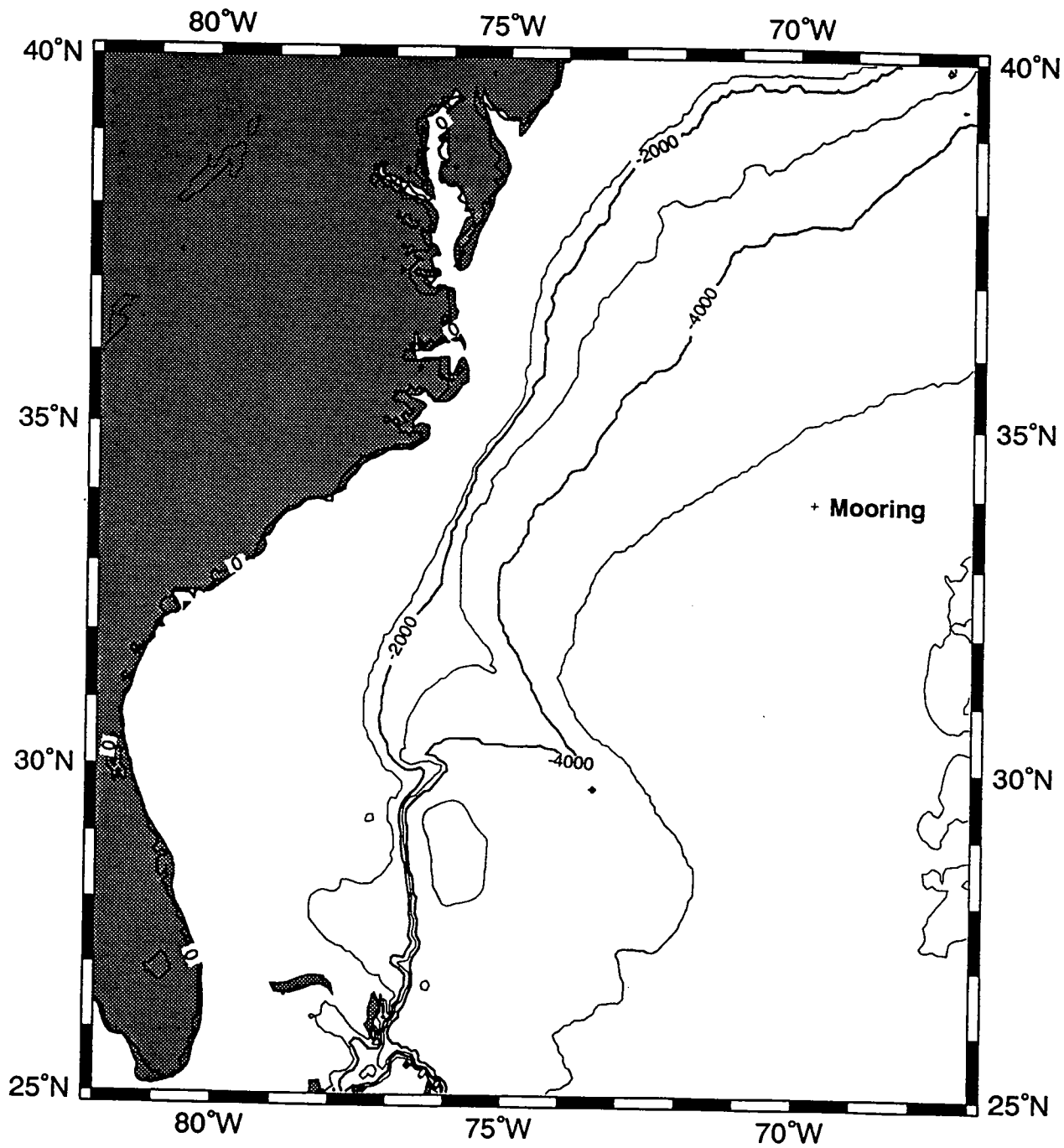
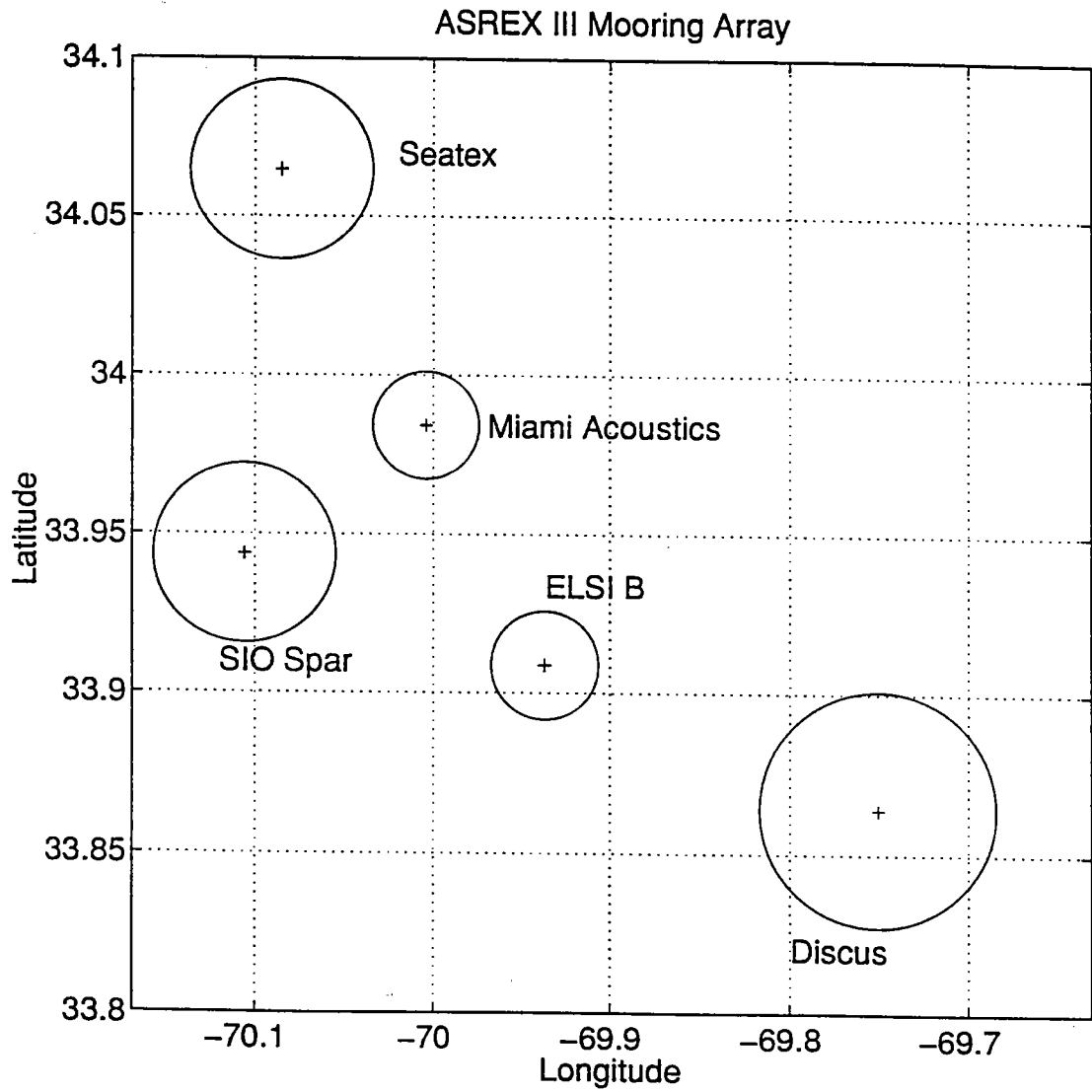


Figure 2.1: Bathymetric map of experiment site.

Table 2.1 lists the locations and durations of the five moorings and Figure 2.2 shows their locations and watch circles. The planned duration for the array was 12 weeks. The actual deployment was longer than this because the ship scheduled for the pickup cruise, the R/V *Endeavor*, was unable to get clearance to sail as planned.

<b>Buoy</b>	<b>Deployed</b>	<b>Recovered</b>	<b>Latitude</b>	<b>Longitude</b>
SIO Spar (WHOI 957)	2041 10 Dec 93	2213 24 Mar 94	33°56.62N	70°06.34W
WHOI Seatex (WHOI 958)	2216 13 Dec 93	1324 23 Mar 94	34°03.89N	70°05.10W
WHOI Discus (WHOI 959)	0613 15 Dec 93	1143 24 Mar 94	33°52.70N	69°44.83W
Miami Acoustics (WHOI 960)	2140 18 Dec 93	1416 21 Mar 94	33°49.05N	70°00.25W
ISO ELSI B (WHOI 961)	0631 19 Dec 93	1234 22 Mar 94	33°54.52N	69°56.20W

**Table 2.1:** Locations and durations of the five moorings. Deployment time is anchor splash, recovery time is when release is fired. Position is for the anchor.



**Figure 2.2: Locations and watch circles of the moorings in the array.**

## 2.2 SIO Soundspeed Mooring

A spar buoy was deployed by SIO to measure acoustic properties of bubble clouds in the upper 7 meters. The buoy had an overall length of 10.66 m and a maximum diameter of 2.43 m. It was composed of three pieces:

- a. A stainless steel tower above the surface holding solar panels, Argos PTTs, the data acquisition system and associated electronics.
- b. A Seward International donut-shaped float with 6400 lb total buoyancy. The central well of this float was filled with a battery pack which was recharged by the solar panels.
- c. A 7 m spar made of 20.31 cm (8 in) outer diameter Aluminum 6061 tubing, extending below the float. All environmental sensors were connected to this spar.

The buoy made measurements of four environmental parameters. Soundspeed was measured by recording the travel times of acoustic pulses between hydrophone pairs at approximately 1 m spacing. The duty cycle was 40 minutes on, 2 Hz pulse rate/pair and 50 minutes off. The frequency of the pulses transmitted during each acquisition period cycled through 3, 5 and 10 kHz, so that 40 minute time series for individual frequencies occur at 4.5 hour intervals. Measurements were made at 0.69, 1.02, 1.58, 1.96, 2.96 4.44, and 6.94 m depth. The acoustic data was logged to hard disk on a Compaq 486 notebook computer.

Temperature was measured using a sensor manufactured by Falmouth Scientific Inc. (F.S.I.) at depths of 0.71, 1.33, 1.97, 3.03, 4.49 and 7.00 m. Conductivity was measured using a sensor manufactured by F.S.I. at depths of 0.71 3.03 and 7.00 m. Dissolved oxygen was measured using a sensor by Royce at 0.65, 3.18, and 7.19 m. The environmental data was logged to disk on an Onset Tattletale 6.

Data was successfully sampled from 10 December 1993 until 22 January 1994. On 22 January, the system unexpectedly shut down due to low power. It is suspected that a seawater ground/short developed and quickly drained the batteries faster than the solar panels could recharge them. Evidence of this has been seen in the time series of battery voltage saved on the Tattletale.

In order to allow the buoy to be attached to the mooring at one side, it was important to limit the tension on the mooring line. This presented a difficulty given the high currents known to be associated with cold-core rings seen at the site during previous deployments. The problem was solved by linking the surface and subsurface floats with an S-tether with a scope of 2.5 consisting of a negatively buoyant upper section and a positively buoyant lower section. This design allowed the mooring to tilt over in high current regimes without greatly increasing the surface tension. A surface tether made of 3/8" trawler chain covered with Tygon tubing was connected to the center of gravity of the buoy. Buoyancy for the surface tether was

provided via 45 Panther-Plast Type 629 floats equally spaced on the top 21 meters. It was presumed that the Tygon tubing would provide sufficient stiffness to prevent the tether from fouling on the spar. This appears to have been the case. The mooring diagram for this instrument is shown in Figure 2.3, and a summary of the instrumentation is presented in Table 2.2.

### **2.3 The Seatex Mooring**

This mooring was instrumented with a Seatex Wavescan™ buoy manufactured by Seatex A/S of Trondheim, Norway. Like the SIO Spar, the Wavescan buoy was tethered to a subsurface float via an S-tether which was designed to decouple the dynamics of the mooring from the motion of the surface float. Like the SIO Spar mooring, the Seatex mooring tether also lost most of the surface floats on the tether due to working in rough seas. The data collected from the buoy is summarized in Table 2.3 and the mooring diagram is shown in Figure 2.4.

### **2.4 The UOP Discus Mooring**

The surface float on this mooring was a 3 m discus buoy outfitted with two meteorological packages, a Vector Averaging Wind Recorder (VAWR) with a full sensor suite, and an Improved Meteorological (IMET) package with a reduced sensor suite. The mooring line was instrumented with 8 Vector Measuring Current Meters (VMCMs), 12 temperature pods (T-POD) made by Brancker Inc. of Toronto, Ontario, Canada, 2 Seacat conductivity/temperature packages, and an inverted Echo-sounder. Details of the instrumentation and sampling are given in Table 2.4. The mooring diagram is shown in Figure 2.5.

### **2.5 The Miami Acoustics Mooring**

The Miami Acoustic Mooring for ASREX III was designed to produce high level acoustic transmissions at frequencies ranging from 100 Hz to 800 Hz and record the acoustic energy backscattered from the ocean surface via a 64 element hydrophone array and a pair of electronic receivers over the course of the 3 month long experiment. The mooring diagram is shown in Figure 2.6, and specifications of the instrumentation and acoustics packages are given in Tables 2.5 and 2.6. From top to bottom the mooring consisted of the following major components:

<b>Instrument</b>	<b>Parameters Measured</b>	<b>Sample Rate</b>	<b>Duty Cycle</b>	<b>Depth</b>
Dissolved Oxygen sensor	Dissolved oxygen	0.5 Hz	Continuous	0.65 m
Acoustic transducer	Soundspeed @ 3, 5 and 10 kHz	2Hz pulse rate	40 min. on, 50 min off cycling through all 3 frequencies	0.69 m
Conductivity/ Temperature sensor	Conductivity, temperature	0.5 Hz (Cond) 2 Hz (Temp)	Continuous	0.71 m
Acoustic transducer	Soundspeed @ 3, 5 and 10 kHz.	2Hz pulse rate	40 min. on, 50 min off cycling through all 3 frequencies	1.02 m
Temperature sensor	Temperature	2 Hz	Continuous	1.33 m
Acoustic transducer	Soundspeed @ 3, 5 and 10 kHz.	2Hz pulse rate	40 min. on, 50 min off cycling through all 3 frequencies	1.69 m
Temperature sensor	Temperature	2 Hz	Continuous	1.97 m
Acoustic transducer	Soundspeed @ 3, 5 and 10 kHz	2 Hz pulse rate	40 min on, 50 min off cycling through all 3 frequencies	2.96 m
Conductivity/ Temperature sensor	Conductivity, temperature	0.5 Hz (Cond) 2 Hz (Temp)	Continuous	3.03 m
Dissolved Oxygen sensor	Dissolved oxygen	0.5Hz	Continuous	3.18 m
Acoustic transducer	Soundspeed @ 3, 5 and 10 kHz.	2 Hz pulse rate	40 min. on, 50 min off cycling through all 3 frequencies	4.44 m
Temperature sensor	Temperature	2 Hz	Continuous	4.49 m
Acoustic transducer	Soundspeed @ 3, 5 and 10 kHz.	2 Hz pulse rate	40 min. on, 50 min off cycling through all 3 frequencies	6.94 m
Conductivity/ Temperature sensor	Conductivity, temperature	0.5 Hz (Cond) 2 Hz (Temp)	Continuous	7.00 m
Dissolved Oxygen sensor	Dissolved oxygen	0.5 Hz	Continuous	7.18 m

**Table 2.2:** Instrumentation, sampling strategy, and days good data for the SIO soundspeed mooring.

Instrument	Fields Measured	Sample Interval	Sample Rate	Days Good Data
Motion Package	Heave Tilts	1 sec	2048 samples every 3 hours	98
	Wave Spectrum	2048 sec	Every 3 hours	

**Table 2.3:** Seatex Wave Mooring. All instrumentation is at surface.

Instrument Type	Fields Measured	Sample Interval	Sample Rate (sec)	Days of Good Data	Depth (meters)
VAWR	WS, WD, AT, SST, RH, BP, SW, LW	450	450	99 except WD	Surface
IMET	WS,WD, AT, RH, SW	450	450	99	Surface
T-POD	T	450	450	99	1
T-POD	T	450	450	99	1
Seacat	S,T	225	225	99	1
VMCM	U,V,T	120	120	90	5
VMCM	U,V,T	120	120	89	10
VMCM	U,V,T	120	120	90	15
VMCM	U,V,T	120	120	90	20
T-POD	T	450	450	99	37.5
VMCM	U,V,T	120	120	89	50
T-POD	T	450	450	99	75
T-POD	T	450	450	99	100
T-POD	T	450	450	99	125
VMCM	U,V,T	120	120	90	150
T-POD	T	450	450	99	175
T-POD	T	450	450	99	200
T-POD	T	450	450	99	230
T-POD	T	450	450	99	260
VMCM	U,V,T	120	120	89	300
T-POD	T	450	450	99	350
T-POD	T	450	450	99	400
Seacat	T,C	225	225	87	450
VMCM	U,V,T	120	120	89	500

WS: Wind speed                      WD: Wind Direction                      RH: Relative Humidity  
BP: Barometric Pressure            AT: Air Temperature                    SST: Sea Surface Temp.  
SW: Short wave Radiation           LW: Long wave Radiation              U,V: East, North Velocity  
T: Temperature                        C: Conductivity

**Table 2.4:** Instrumentation and data return from the UOP meteorological/oceanographic mooring. Total deployment time for this mooring was 99 days. An inverted Echo-sounder package was also deployed at 30 meters, but did not record any data.



<b>Instrument</b>	<b>Fields Measured</b>	<b>Sample Rate</b>	<b>Sample Interval</b>	<b>Depths relative to top plate</b>	<b>Days Good Data</b>
Conical Beam Sonars (4)	Backscatter @55, 110, 200 and 300 Khz	2 Hz	27 minutes every 12 hours	Surface	10
Water Structure Profiler (WASP)	Backscatter @200 kHz	1/6 sec	Continuous	0.25m bins, 10–50m above instrument	10
Sidescan sonars (4)	Backscatter, doppler velocity @ 100 kHz	2 Hz	27 minutes every 12 hours	Surface	10
Wide-band, omnidirectional hydrophone	Ambient noise spectrum		Every 1 hour	At instrument	10
Temperature sensor	Temp,		Every 1 hour	At instrument	10
Conductivity sensor	Cond.		Every 1 hour	At instrument	10
Pressure sensor	Pressure		Every 1 hour	At instrument	10
Motion Package	Tilt, Orientation		Every 1 hour	At instrument	10
SeaData TDR	Temp, Pressure	1/450 sec			84
Hydrophone array (see Table 2.6 for details)	Sound level at 100, 200, 400 and 800 Hz				84

**Table 2.5:** Miami Acoustics Mooring, Instrumentation and Data Return. One TDR, located on the disk buoy, was inadvertently turned off when the endcap was placed on the instrument. This instrument functioned normally during post-cruise calibrations and the data loss, while unfortunate, was apparently due to human error and/or a design flaw (twisting of the end cap to line up the securing latches apparently caught the switch and turned it off).

## *University of Miami Low Frequency Source and Receiver Arrays*

The UM source and receiver arrays are autonomous and general purpose instruments that can be moored at sea for periods of months and transmit and receive complex acoustical signals under computer control. The source is constructed with four arrays of air-backed, pressure-compensated transducers with center frequencies of 100, 200, 400 and 800 Hz. that transmit at a level of ~200 dB// $\mu$ Pa @ 1 m. The two receiver packages each handle a 32 element hydrophone array with 20 gigabytes of storage capacity. The packages can be moored separately or on the same mooring to form a 64 element array.

### **Source**

•Frequencies	100	200	400	800	Hz
•Source Levels	196	197	196	198	dB// $\mu$ Pa @ 1 m
•Bandwidth	25	66	133	266	Hz
•Pulse period	.040	.015	.0075	.0038	sec
•Operating depth	300 m				
•Duration	12 week, 20% Duty cycle, (full complement alkaline batteries)				
•Signal types	Fm, M-sequences, CW pulses, Golay codes, anything programmable within bandwidth				
•Size	size: ~5 ft dia x 18 ft long (~1.5 m dia x 5.5 m long)				
•Weight	-6218 lbf (27.7 kN) -- in air -550 lbf (2.4 kN) -- in sea water, bladders evacuated -187 lbf (832 N) -- in sea water, bladders full of air				

### **Receivers**

•Reception	4 x Fc sample and store or phase coherent demodulation with coherent circular averaging
•Storage	5 gigabytes expandable to 20 in each receiver
•Hydrophone spacing	2 x 16 element and 1 x 32 element arrays with .94 m spacing (3.1 ft) (half wavelength for 800 Hz) 2 x 16 element and 1 x 32 element arrays with 1.88 m spacing (6.2 ft) (half wavelength for 400 Hz)
•Sensitivity	178 db//1V/ $\mu$ Pa @ 1m
•Size	~4 ft dia x 9 ft long (~1.2 m dia x 2.7 m long)/ea receiver
•Weight	-3743 lbf (16.7 kN) in air +670 lbf (3.0 kN) buoyant in s.w.

**Table 2.6:** Specifications of the U. Miami Acoustic Array.

### *Extended Life Sonar Instrument (ELSI) - IOS/Canada*

This instrument used high frequency acoustics to measure the content and nature of bubble plumes that were generated by breaking surface gravity waves at high sea states. Parameters of the ELSI deployed from this mooring are described in Table 2.5.

### *Disk Buoy*

A disk shaped syntactic foam buoy package provided most of the buoyancy required to maintain high tension in the subsurface taut mooring. It provided approximately 3100 lbs of positive buoyancy at depths up to 2000 m. A pair of Argos satellite Platform Terminal Transmitters (PTTs), one oriented up and the other down, were mounted on the side of the buoy to provide location information to a shore station should the mooring have surfaced prematurely. A Sea Data/Pacer/WHIS temperature-depth recorder (TDR) was mounted on the top of the disk buoy and recorded the temperature and pressure every 7.5 minutes over the course of the experiment.

### *Acoustic Transmitter ("Miami Sound Machine")*

A 5.3 meter long, 6100 lb (in air) package contained an electronic signal generating system powered by alkaline batteries, a syntactic foam flotation module that reduced its weight in water to under 750 lbs, and an array of acoustic transducers mounted in an aluminum framework that could broadcast acoustic signals at levels on the order of 200 dB//1  $\mu$ Pa @ 1 m at four frequencies (100 Hz, 200 Hz, 400 Hz, and 800 Hz). This instrument transmits a series of acoustic pulses and coded signals that are listened for by the receiver packages/acoustic array described below. The transmitter also provided a clock signal that was transmitted down a 20 meter long electro-mechanical cable to the uppermost receiver system. This technique assured that the source and receivers were always "in synch" with one another.

### *Acoustic Receivers/Hydrophone Array*

There were two receiving packages on the Miami mooring each of which recorded signals received by 32 of the 64 total hydrophones distributed between them. The receiver packages contain electronics and tape recording systems capable of recording 25 gigabytes of data each. The electronics are powered by a series of alkaline battery packs mounted in cylindrical aluminum pressure housings. The pressure housings are recess mounted in custom built syntactic foam buoyancy modules, and bolted to an aluminum framework. Each receiver package weighs about 4000 lbs in air and is 3.1 meters long. In seawater, however, the packages provide over 650 lbs of positive buoyancy. In addition to recording acoustic signals, the receivers also monitor and record tilt and ambient pressure. TDR's were mounted on each

end of each receiver to provide additional records of pressure and ambient temperature. A Benthos XT-6000 acoustic beacon, modified to include a pressure sensor, was mounted on the uppermost receiver and was used to telemeter its pressure (depth) back to a DS7000 deck unit when interrogated at the proper frequency. This was useful during the deployment operation as it gave a real time indication that the instrument was moored at its proper depth.

The hydrophone array consisted of 64 HT1 hydrophones spaced to provide beam-forming capabilities at all of the frequencies output by the transmitter. The hydrophones were mounted in aluminum pipes that were whipped to a Kevlar-based electromechanical cable that has a breaking strength in excess of 12,000 lb. In addition, a 3/8" diameter 3x19 jacketed wire rope ran in parallel to provide backup protection, should the Kevlar strength member be severed (i.e., by fish bite). The array also featured a 3-strand fairing to reduce cable strumming. Just below the lower receiver system was a 200 meter length of SAIC Quiet Cable® which was also used to reduce cable strumming which can interfere with acoustic measurements.

The remainder of the mooring consisted of 3/8" wire rope, 1/2" chain, glass buoyant spheres, and a pair of Benthos 865A acoustic releases mounted in parallel, all of which were chained to a 7000 lb cast iron anchor (Figure 2.6).

## **2.6 The ELSI B Mooring**

This mooring included an ELSI B instrument platform which included a number of sonar instruments as shown on Figure 2.7. These were:

- a. 6 upward looking conical beam sonars operating at frequencies of 28, 50, 88, 100, 200, and 400 kHz.
- b. A fixed 100 kHz sidescan sonar identical to that deployed on the Miami acoustics mooring.
- c. A 100 kHz sidescan sonar mounted on a rotating base allowing it to scan 360 degrees in azimuth every 77 seconds. Because of the extra time required to move the sonar, the overall ping rate was reduced to 1.67 Hz.
- d. Instruments to measure ambient sound and environmental parameters. The sonars collected data for 27 minutes every 6 hours.

Additional instrumentation on the mooring included an Anderaa temperature chain with thermistors every 5 meters below the top plate of ELSI B, an S4 current meter at 7.5 m below the top plate of ELSI B and a 12 channel WOTAN (wind observation through ambient noise) instrument 70 m below the top plate of ELSI B. Table 2.7 lists the ELSI B mooring instrumentation.

Figures 2.8 and 2.9 show the positions of the Discus and Seatex buoys from System Argos. Both buoys show a consistent pattern, lying to the northeast of the moorings during December, shifting around to the east during January, and then more to the southeast during February, and finally to the south during March. These positions reflect the prevailing currents over the course of the deployment.

<b>Instrument</b>	<b>Parameters Measured</b>	<b>Sample Rate</b>	<b>Sample Frequency</b>	<b>Depths relative to top plate</b>	<b>Days Good Data</b>
Conical beam sonars	Backscatter at 28, 50, 88, 100, 200, and 400 kHz	1557 sec (2600 pings @ 1.67 Hz)	12 hours	Ocean Surface	90
Fixed 100 kHz Sidescan	Backscatter, Doppler velocities out to ~300 m	1557 sec. (2600 pings @ 1.67 Hz)	12 hours	Ocean Surface	90
Rotating 100 kHz Sidescan	Backscatter, Doppler velocities out to ~300 m	1557 sec. (2600 pings @ 1.67 Hz)	12 hours	Ocean Surface	90
Environmental Sensor Pack	Temperature, conductivity, depth			1	90
Thermistor String	Temperature	1200 sec	1200 sec	10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60	82
WOTAN	Ambient noise in 12 channels	15 sec	180 sec	70	90

**Table 2.7:** IOS ELSI B Mooring, Instrumentation and Data Return. This mooring was deployed for a total of 90 days. An S4 current meter was also deployed on this mooring but was severely damaged on recovery with consequent loss of data.

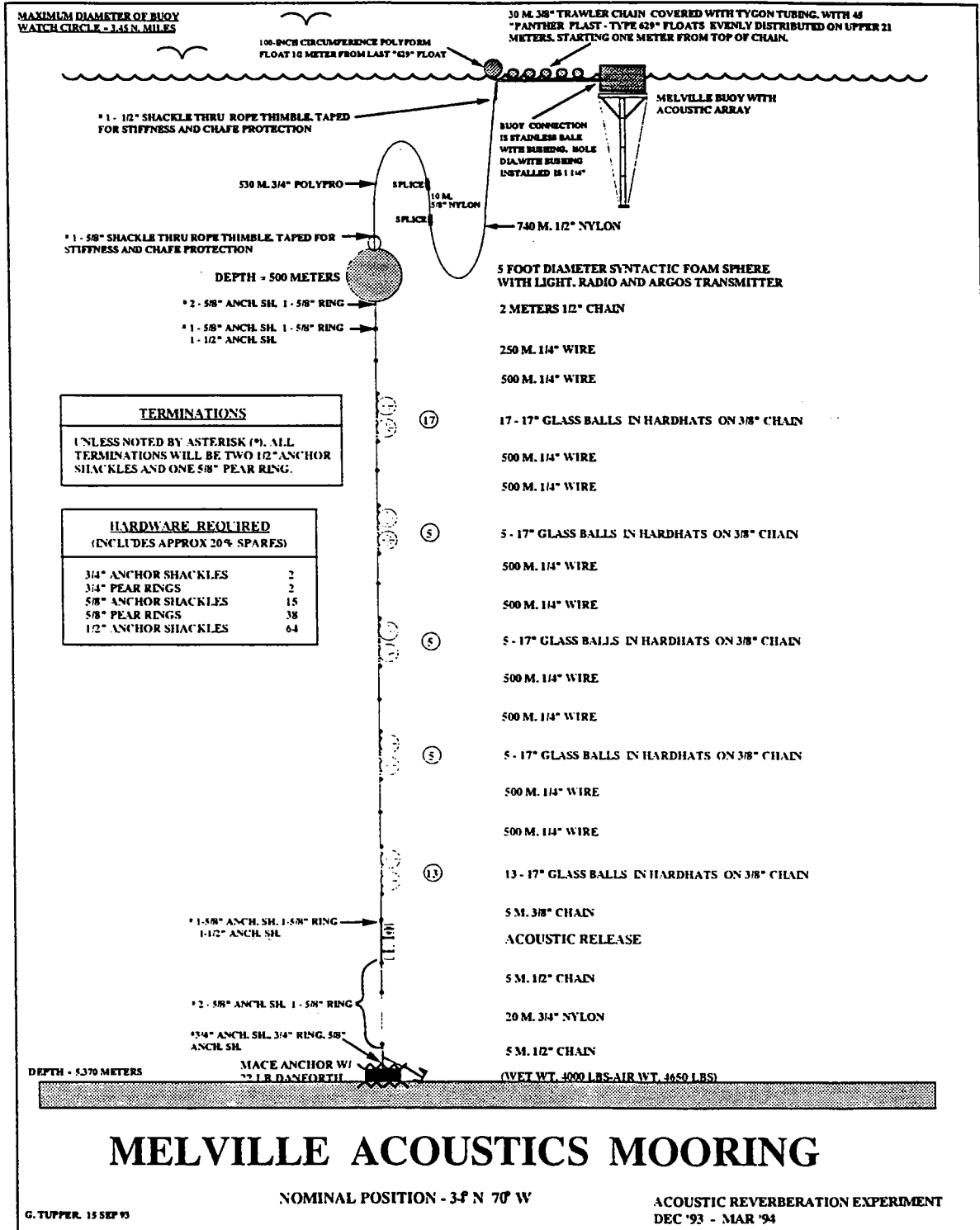


Figure 2.3: Diagram of SIO Soundspeed Mooring.

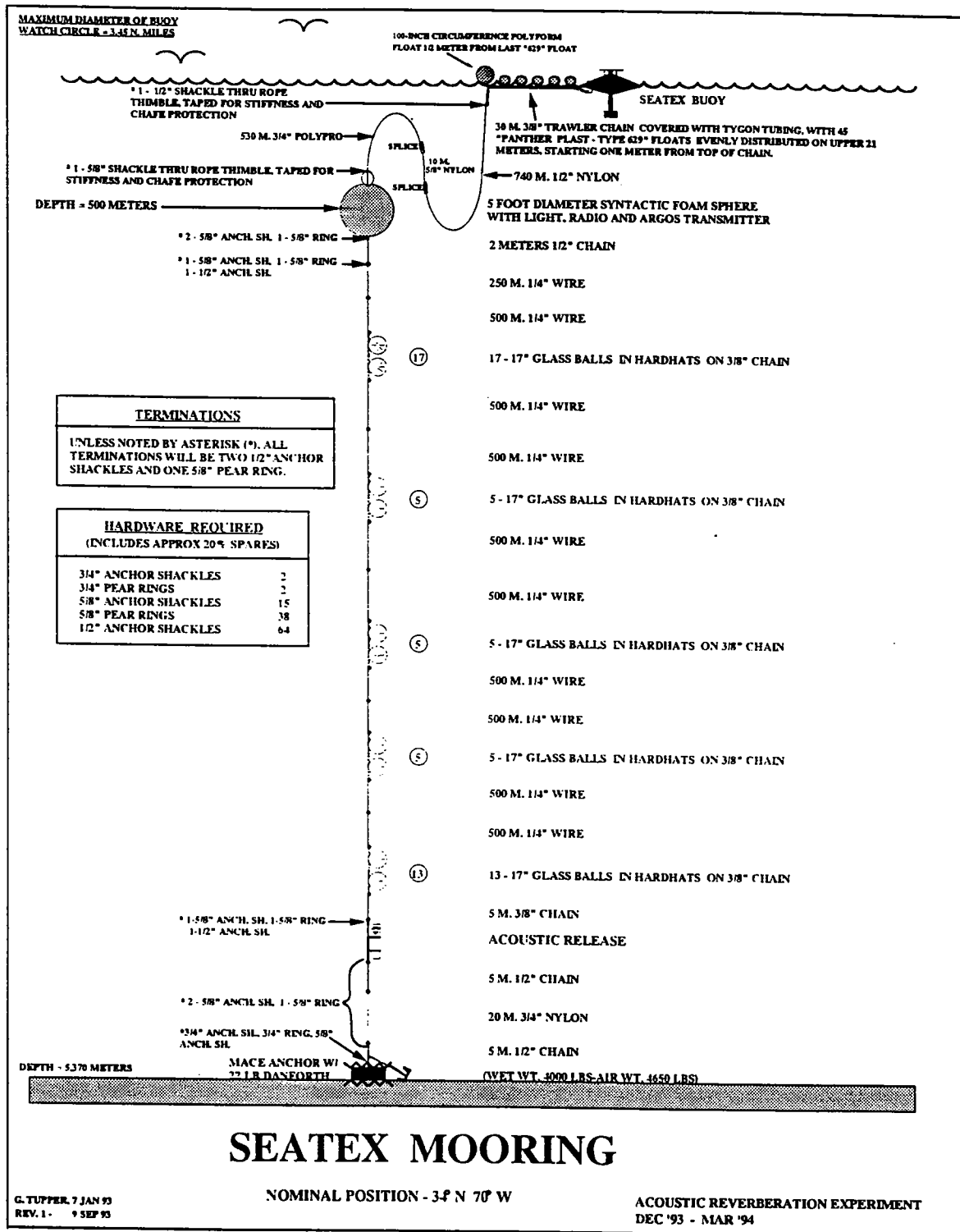


Figure 2.4: Diagram of WHOI Seatex Mooring.



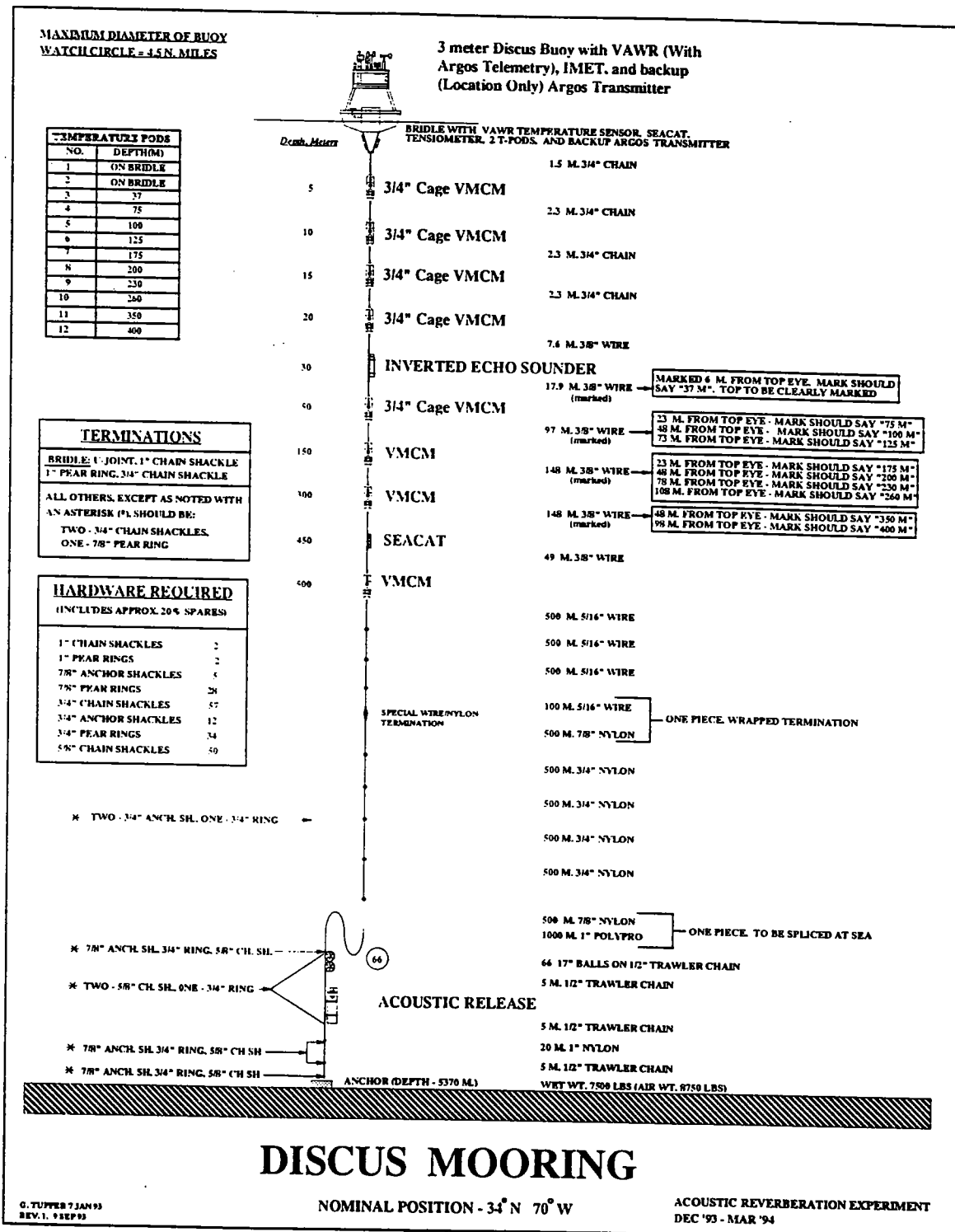


Figure 2.5: Diagram of WHOI Discus Mooring.

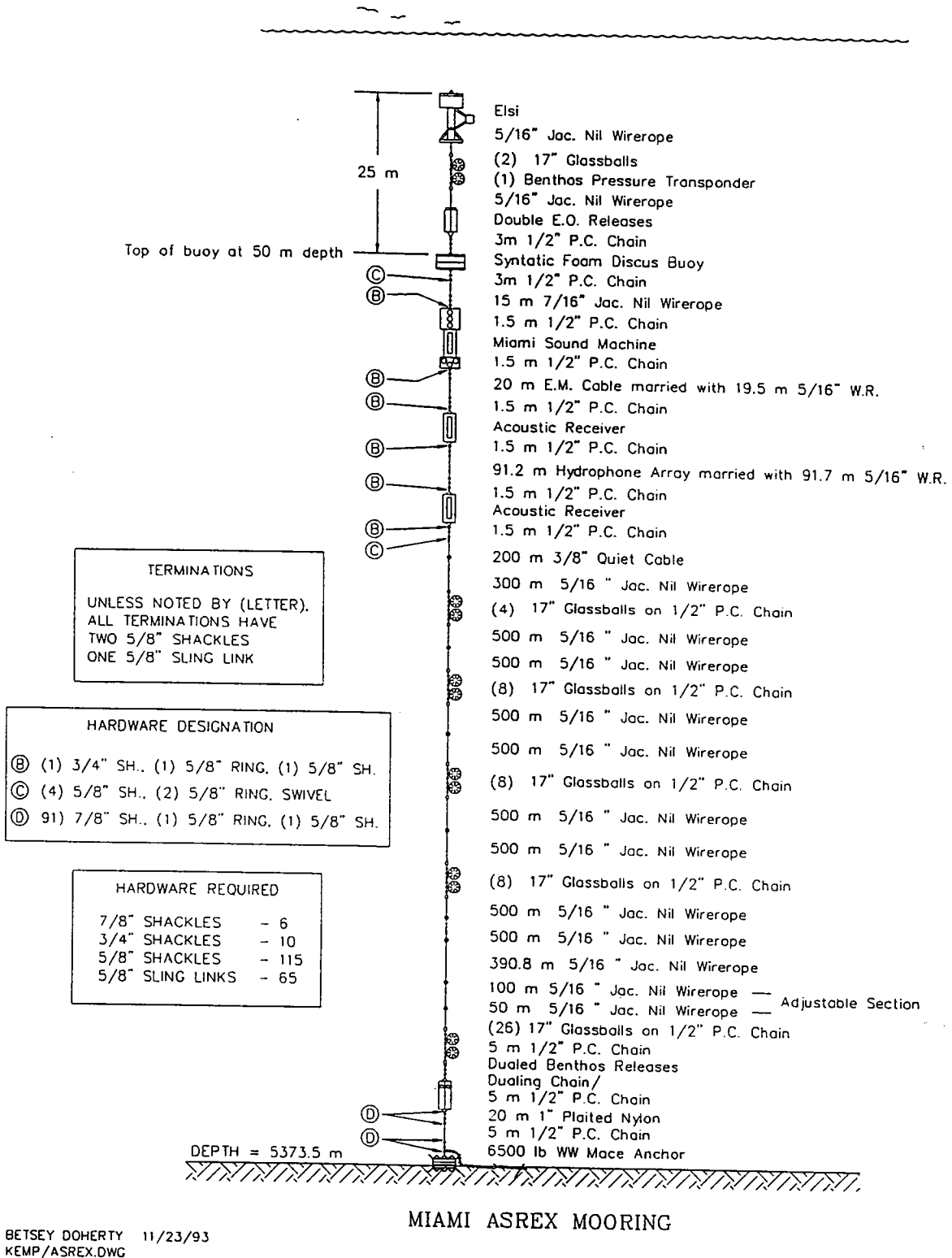


Figure 2.6: Diagram of Miami Acoustics Mooring.

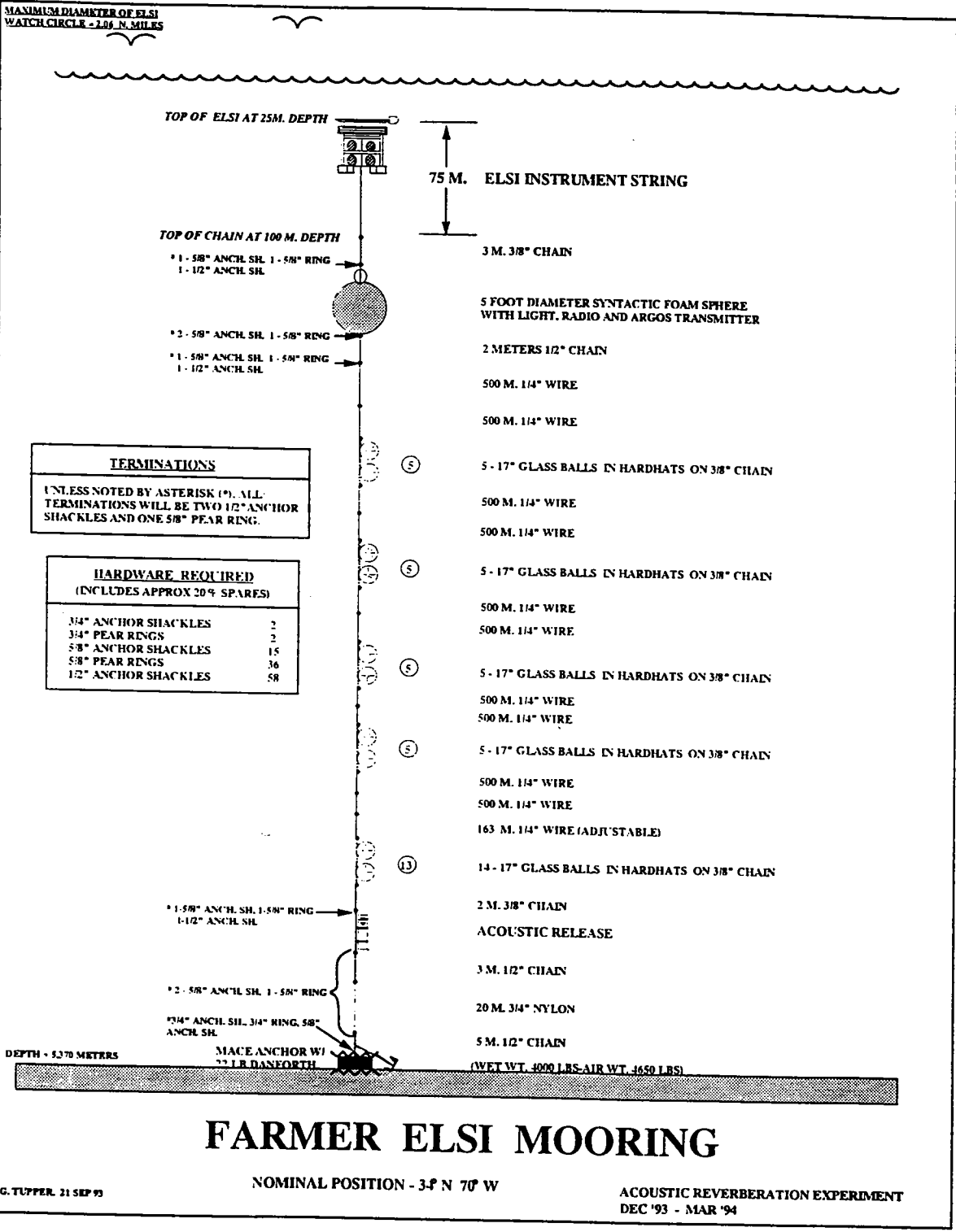


Figure 2.7: Diagram of IOS ELSI B Mooring.

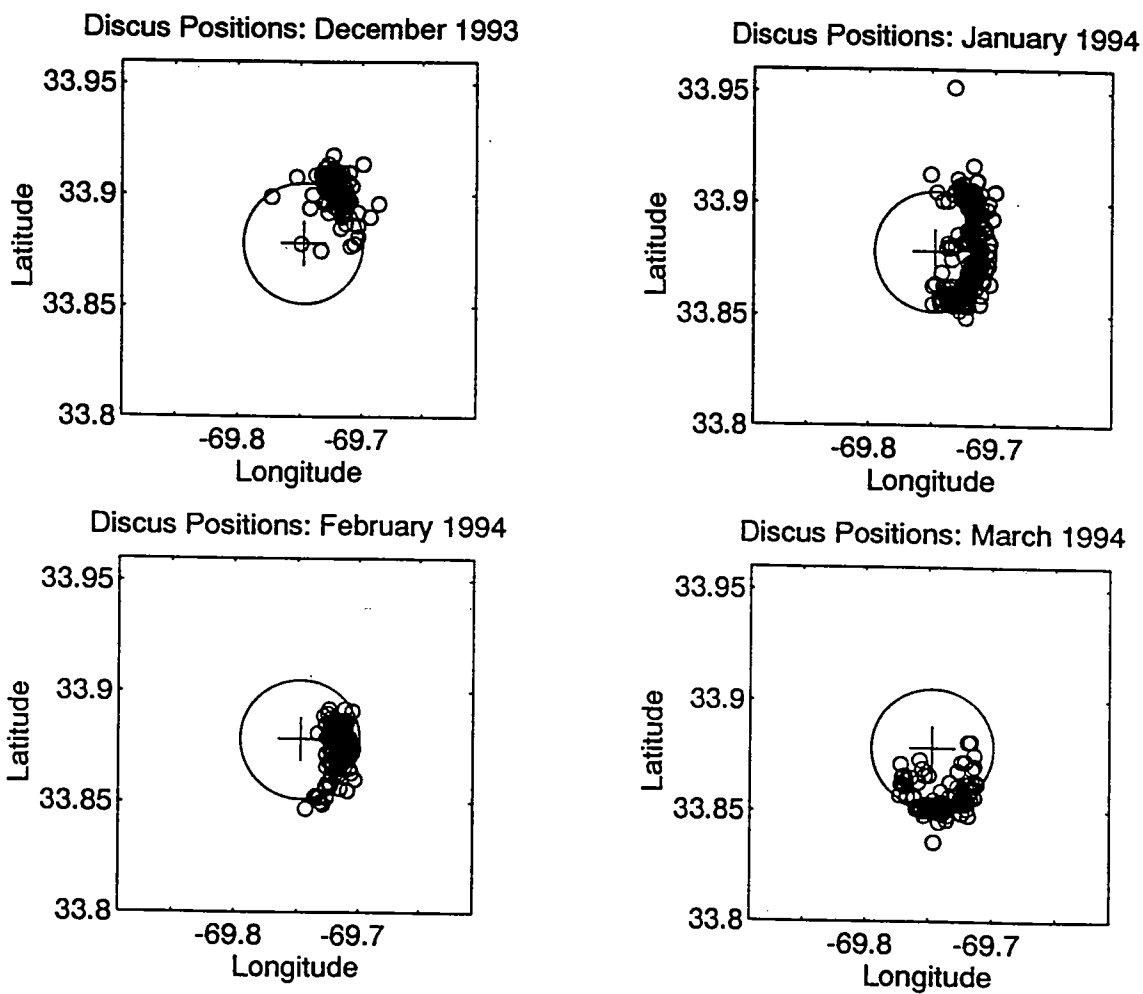


Figure 2.8: Argos positions of Discus buoy.

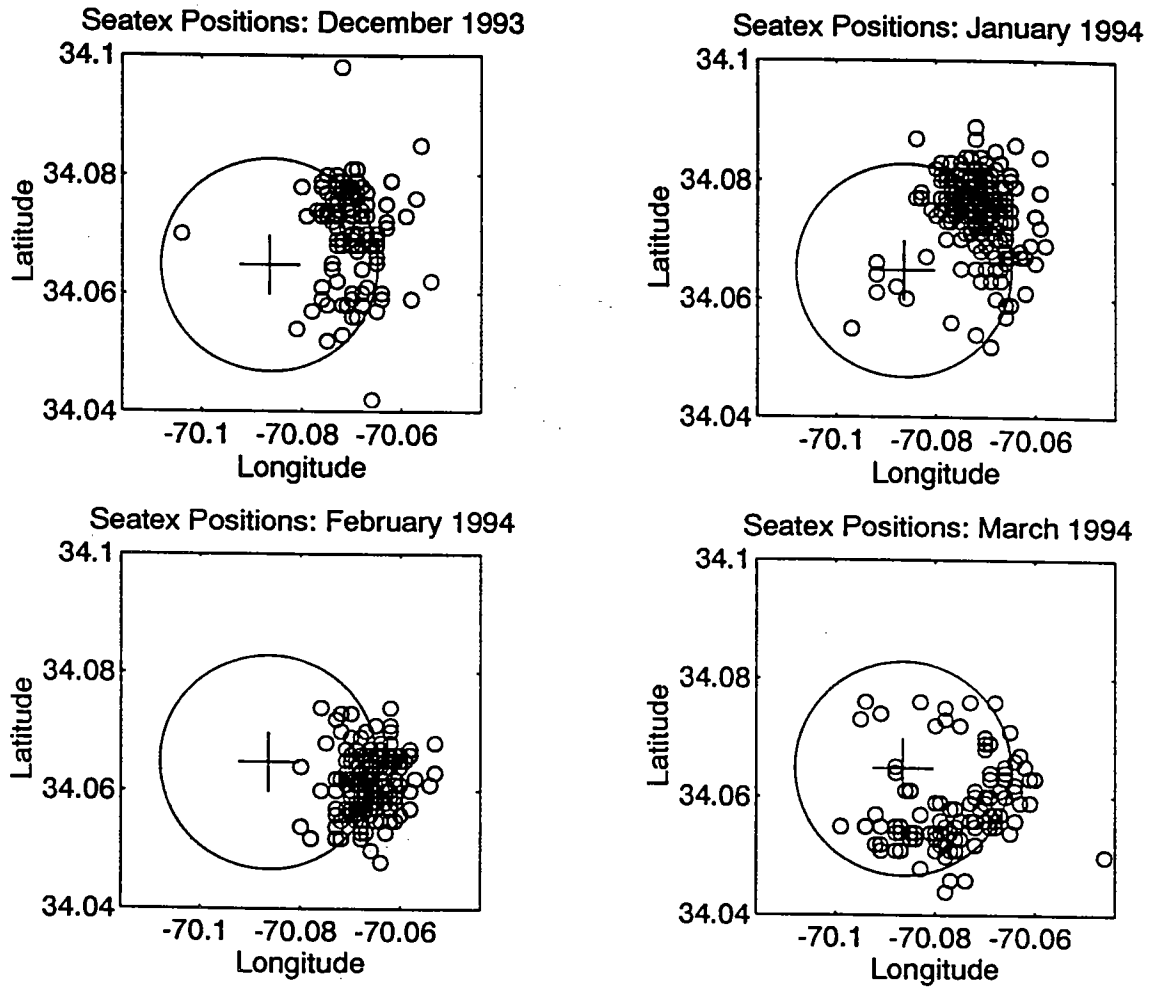


Figure 2.9: Argos positions of Seatex buoy.

