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August 1998

Pan American Climate Study (PACS)

Mooring Recovery and Deployment Cruise Report
R/V *Thomas Thompson* Cruise Number 73
28 November to 26 December 1997

by

Richard P. Trask
Robert A. Weller
William M. Ostrom
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Upper Ocean Processes Group
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

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Abstract

Three surface moorings were recovered and redeployed during R/V *Thomas Thompson* cruise number 73 in the eastern equatorial Pacific as part of the Pan American Climate Study (PACS). PACS is a NOAA-funded study with the goal of investigating links between sea-surface temperature variability in the tropical oceans near the Americas and climate over the American continents. The three moorings were deployed near 125°W, spanning the strong meridional sea-surface temperature gradient associated with the cold tongue south of the equator and the warmer ocean north of the equator, near the northernmost, summer location of the Intertropical Convergence Zone. The moored array was deployed to improve the understanding of air-sea fluxes and of the processes that control the evolution of the sea surface temperature field in the region.

Two surface moorings, located at 3°S, 125°W and 10°N, 125°W, belonging to the Upper Ocean Processes (UOP) Group at the Woods Hole Oceanographic Institution (WHOI), were recovered after being on station for eight months and redeployed. Two eight-month deployments were planned. A third mooring deployed at the equator and 128°W by the Ocean Circulation Group at the University of South Florida (USF) was also recovered and redeployed. The USF mooring, unfortunately, had to be recovered immediately following redeployment due to a problem with the buoy and instrumentation.

The buoys of the two WHOI moorings were each equipped with meteorological instrumentation, including a Vector Averaging Wind Recorder (VAWR), and an Improved METeorological (IMET) system. The WHOI moorings also carried Vector Measuring Current Meters, single point temperature recorders, and conductivity and temperature recorders located in the upper 200 meters of the mooring line. In addition to the instrumentation noted above, a variety of other instruments, including an acoustic current meter, acoustic doppler current meters, bio-optical instrument packages and an acoustic rain gauge, were deployed during the PACS field program. The USF mooring had an IMET system on the surface buoy and for oceanographic instrumentation, two RD Instruments acoustic doppler current profilers (ADCPs), single-point temperature recorders, and conductivity and temperature recorders. Conductivity-temperature-depth (CTD) profiles were made at each mooring site and during the transit between mooring locations.

This report describes, in a general manner, the work that took place during R/V *Thomas Thompson* cruise number 73. A description of the WHOI moored array and instrumentation is provided. Details of the mooring designs and preliminary data from the CTD profiles are included.

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Section 1: Introduction

The R/V *Thomas Thompson* cruise number 73 (TN 073) departed Honolulu, Hawaii, on 28 November 1997, at 1700 hours UTC. The purpose of the cruise was to recover and redeploy two Woods Hole Oceanographic Institution (WHOI) surface moorings and one University of South Florida (USF) surface mooring. All of the moorings were part of the Pan American Climate (PACS) Study funded by the National Oceanic and Atmospheric Administration (NOAA). This was the second of three cruises planned for the experiment. The final recovery of all moorings is planned for September/October 1998. The PACS cruise schedule is shown in Figure 1.

The cruise involved personnel from the Upper Ocean Processes (UOP) Group at WHOI, and personnel from USF. Appendix 1 lists the cruise participants. Figure 2 shows the cruise track and the mooring locations; Table 1 lists the deployment and recovery dates for the first setting of the moored array (referred to as PACS 1) as well as the surveyed anchor positions; and Table 2 lists the deployment dates and positions of the moorings that were redeployed during TN 073. The second deployment of the PACS moorings is referred to as PACS 2.

Four Sounding Oceanographic Langrangian Observer (SOLO) instruments belonging to Scripps Institution of Oceanography (SIO) were deployed during the cruise. A total of 31 conductivity-temperature-depth (CTD) casts were made throughout the cruise. Appendix 2 contains a listing of the CTD positions, start times and maximum depth of the stations, as well as a plot of the CTD station locations.

This report has a total of three sections including this brief introduction. The second section describes the PACS moored array with emphasis on the WHOI moorings and their instrumentation. This section also includes a description of the USF moorings and their instrumentation. The third section presents a chronology of the cruise.

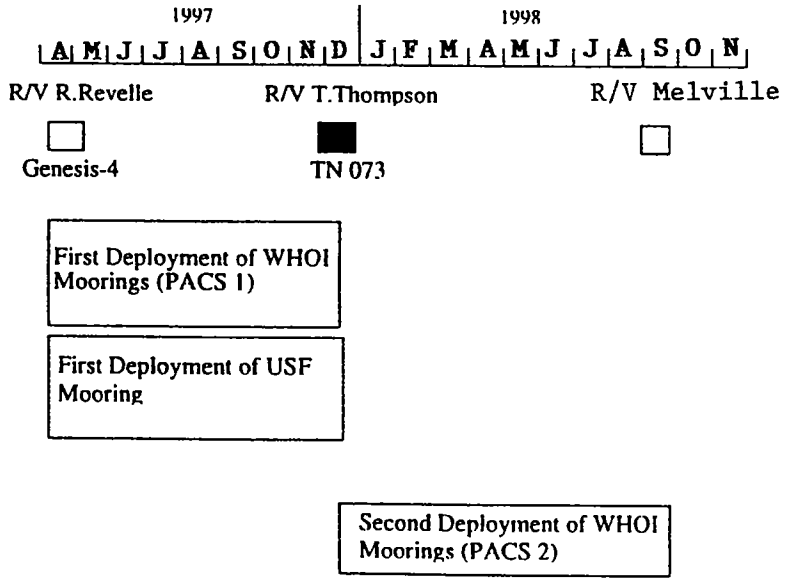


Figure 1: PACS mooring cruise schedule.

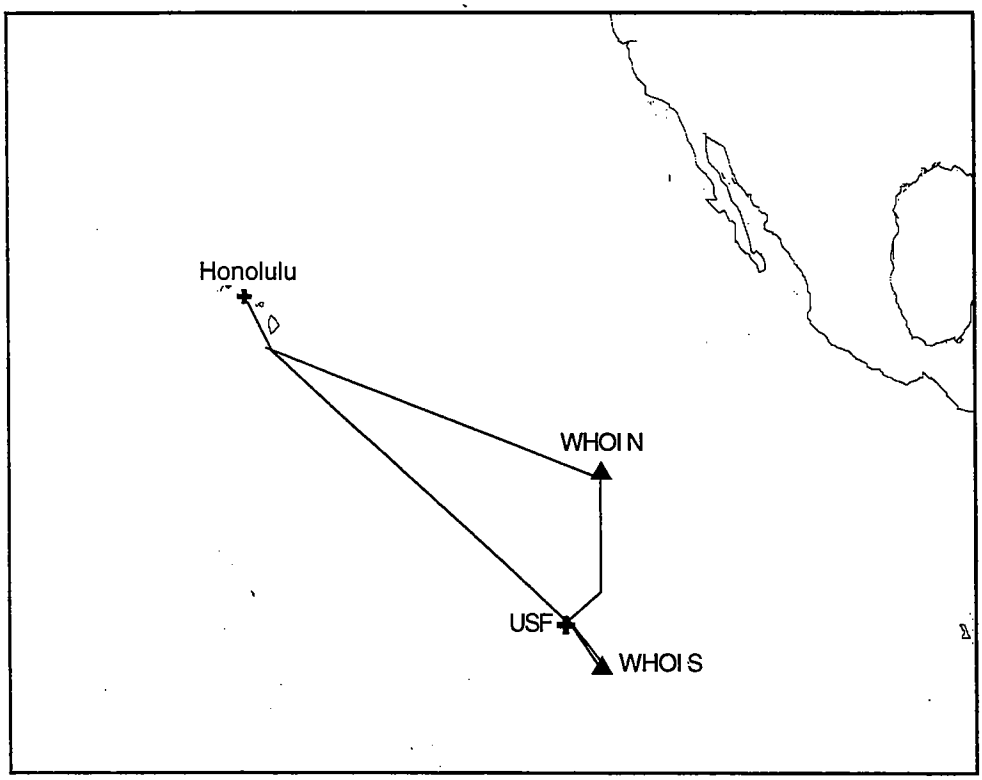


Figure 2: Cruise track and mooring locations.

Table 1: PACS 1 mooring deployment/recovery information

Mooring	Deployment Date and Time	Recovery Date	Anchor Position
WHOI PACS - South Discus Buoy (WHOI Moor. Reference No. 1014)	21 April 1997 @0002 UTC	7 December 1997 @1548 UTC	2°46.78'S 124°39.38'W
USF Toroid Buoy	24 April 1997 @2154 UTC	10 December 1997 @ 1828 UTC	00°00.39'N 127°58.34'W
WHOI PACS - North Discus Buoy (WHOI Moor. Reference No. 1015)	29 April 1997 @2135 UTC	17 December 1997 @ 1533 UTC	9°58.99'N 125°23.39'W

Table 2: PACS 2 mooring deployment information

Mooring	Deployment Date and Time	Anchor Position
WHOI PACS South Discus Buoy WHOI Mooring Reference No. 1020	9 December 1997 @ 0036 UTC	2° 46.231'S 124° 39.733' W
WHOI PACS North Discus Buoy WHOI Mooring Reference No. 1021	19 December 1997 @ 0119 UTC	9° 55.787' N 125° 24.772' W

Section 2: The Moored Array

Three surface moorings, previously deployed during the Genesis 4 cruise of the R/V *Roger Revelle* in April 1997, were recovered and redeployed during TN 073. Two of the three moorings were prepared and deployed by the UOP Group at WHOI. The WHOI moorings were nominally located in the eastern Pacific at latitudes 10°N and 3°S along longitude 125°W. In this report the WHOI moorings are referred to as either North or South. The first deployment of WHOI moorings is referred to as the PACS 1 moorings and the second deployment as PACS 2. Therefore, there is a PACS 1 North and South mooring and a PACS 2 North and South mooring. Both WHOI moorings from both the PACS 1 and 2 deployments were heavily instrumented with both meteorological and oceanographic instrumentation. The third mooring was prepared by personnel from the Ocean Circulation Group at USF. The USF mooring was deployed on the equator to the west of the WHOI moorings. Details about the WHOI moorings and the USF mooring can be found below in their respective sections.

A. WHOI Surface Moorings

The PACS 1 North and South moorings are shown schematically in Figures 3 and 4 respectively. The PACS 2 North and South mooring drawings are shown in Figures 5 and 6 respectively. The WHOI moorings are an inverse catenary design utilizing wire rope, chain, nylon and polypropylene line. Each mooring has a scope of 1.22 (Scope = mooring slack length/water depth). The surface buoy is a three-meter diameter discus buoy with a two-part aluminum tower and rigid bridle. Figures 7 and 8 schematically show the PACS 1 North and South discus buoys respectively with both tower- and bridle-mounted instrumentation. Figures 9 and 10 schematically show the PACS 2 North and South discus buoys respectively.

The design of the WHOI surface moorings took into consideration the predicted currents, winds, and sea state conditions expected during the deployment duration. Further they they were constructed using hardware and designs already proven in the recent Arabian Sea deployment.

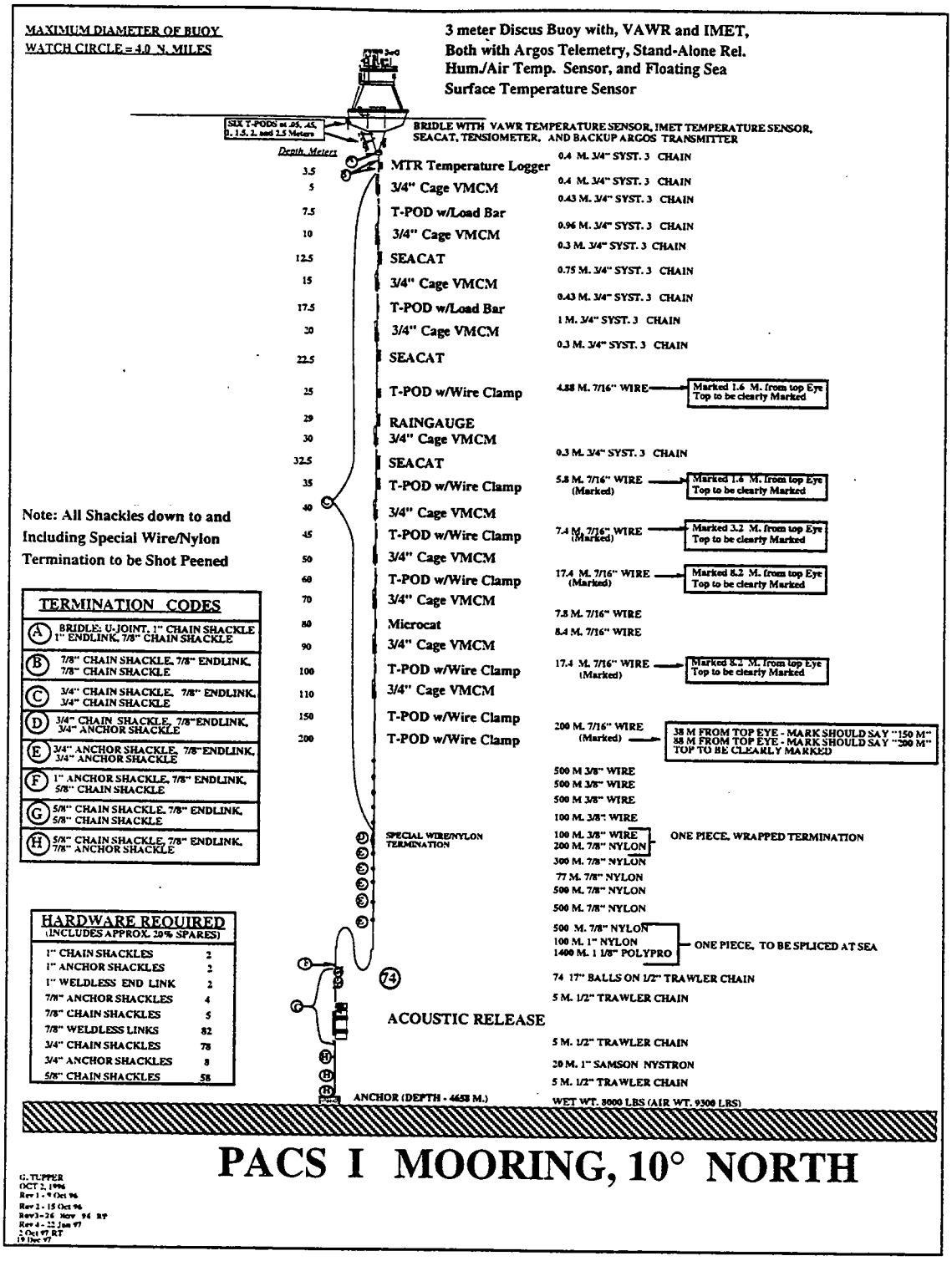


Figure 3: WHOI PACS 1 North mooring schematic

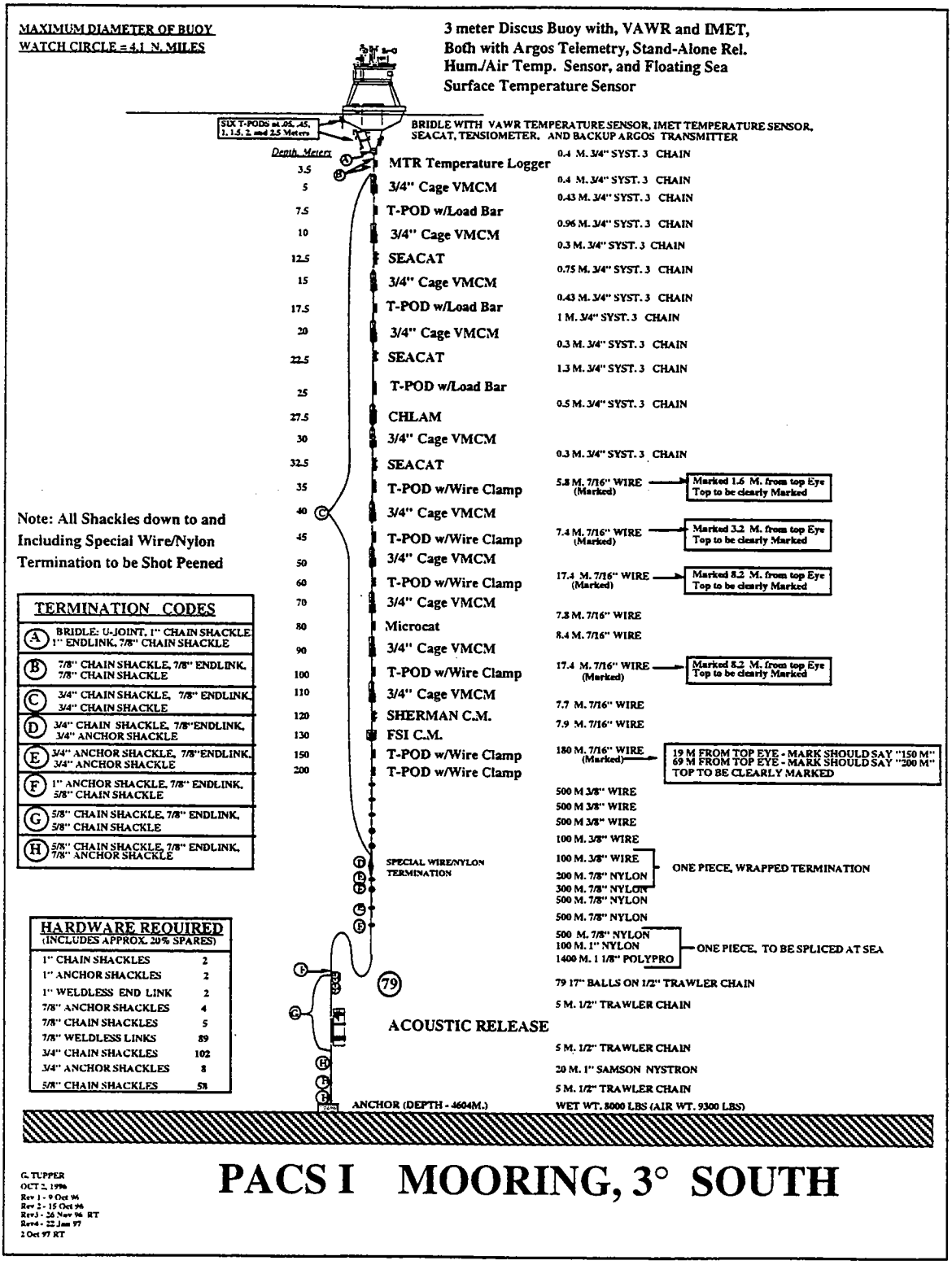


Figure 4: WHOI PACS 1 South mooring schematic

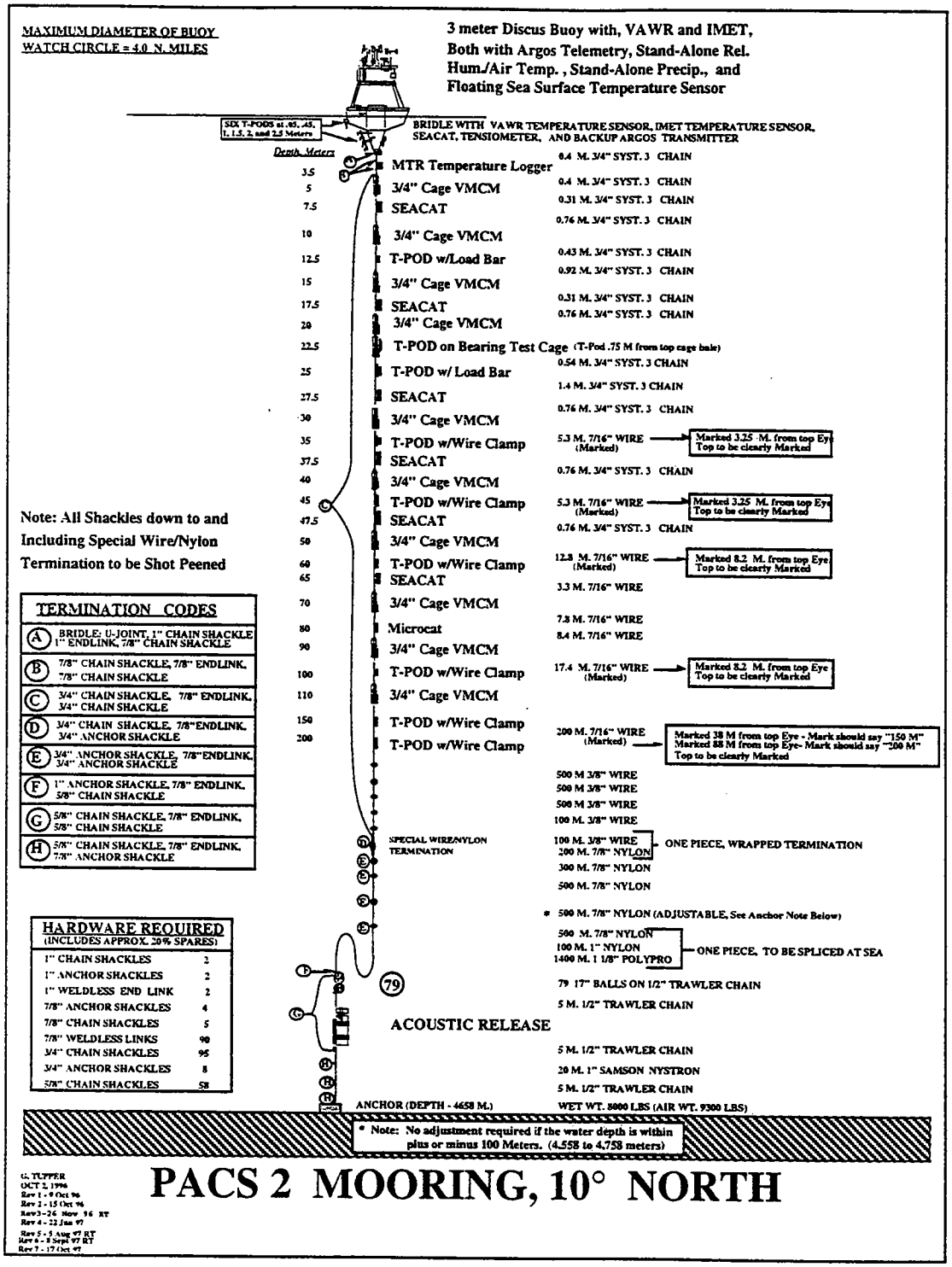


Figure 5: WHOI PACS 2 North mooring schematic

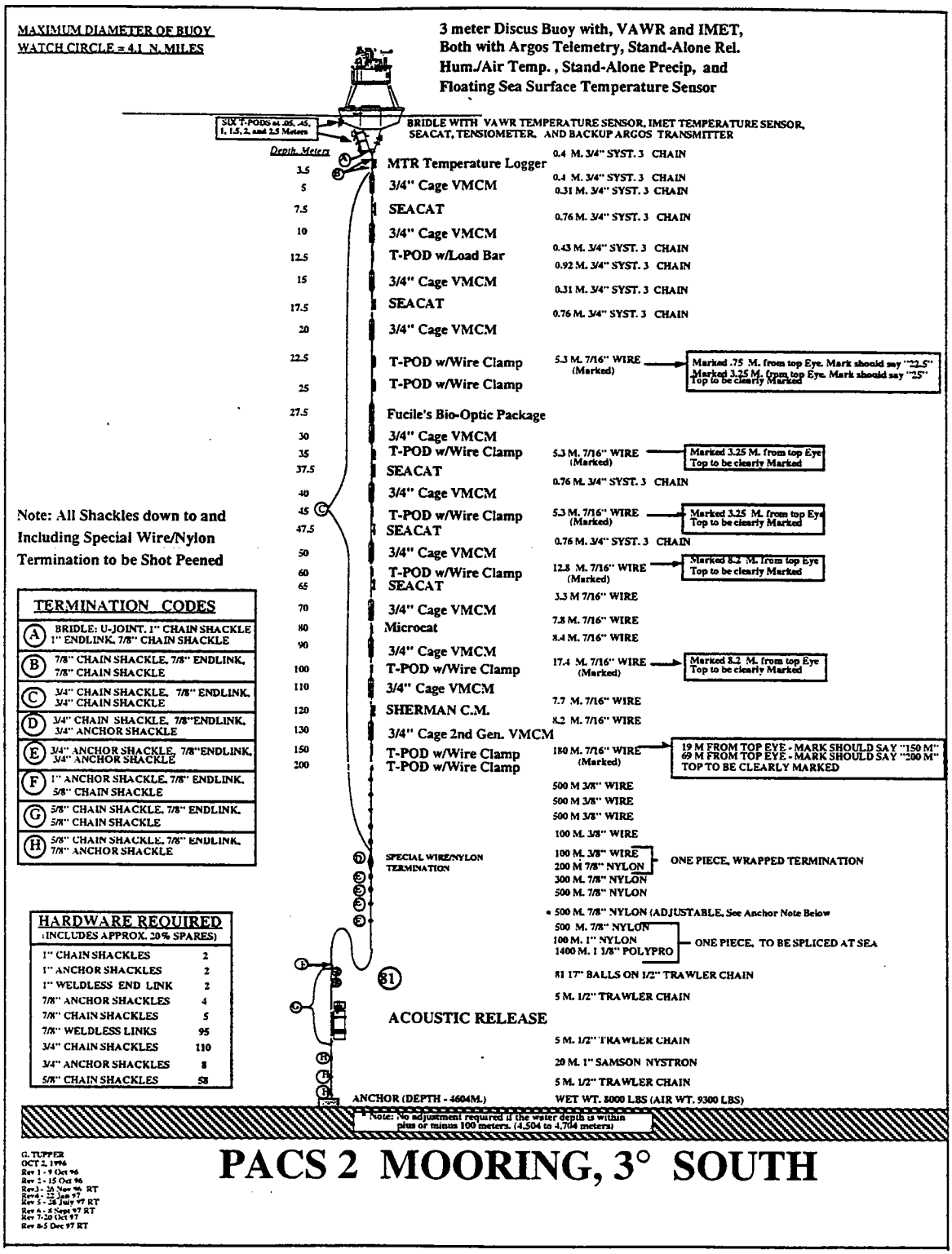


Figure 6: WHOI PACS 2 South mooring schematic

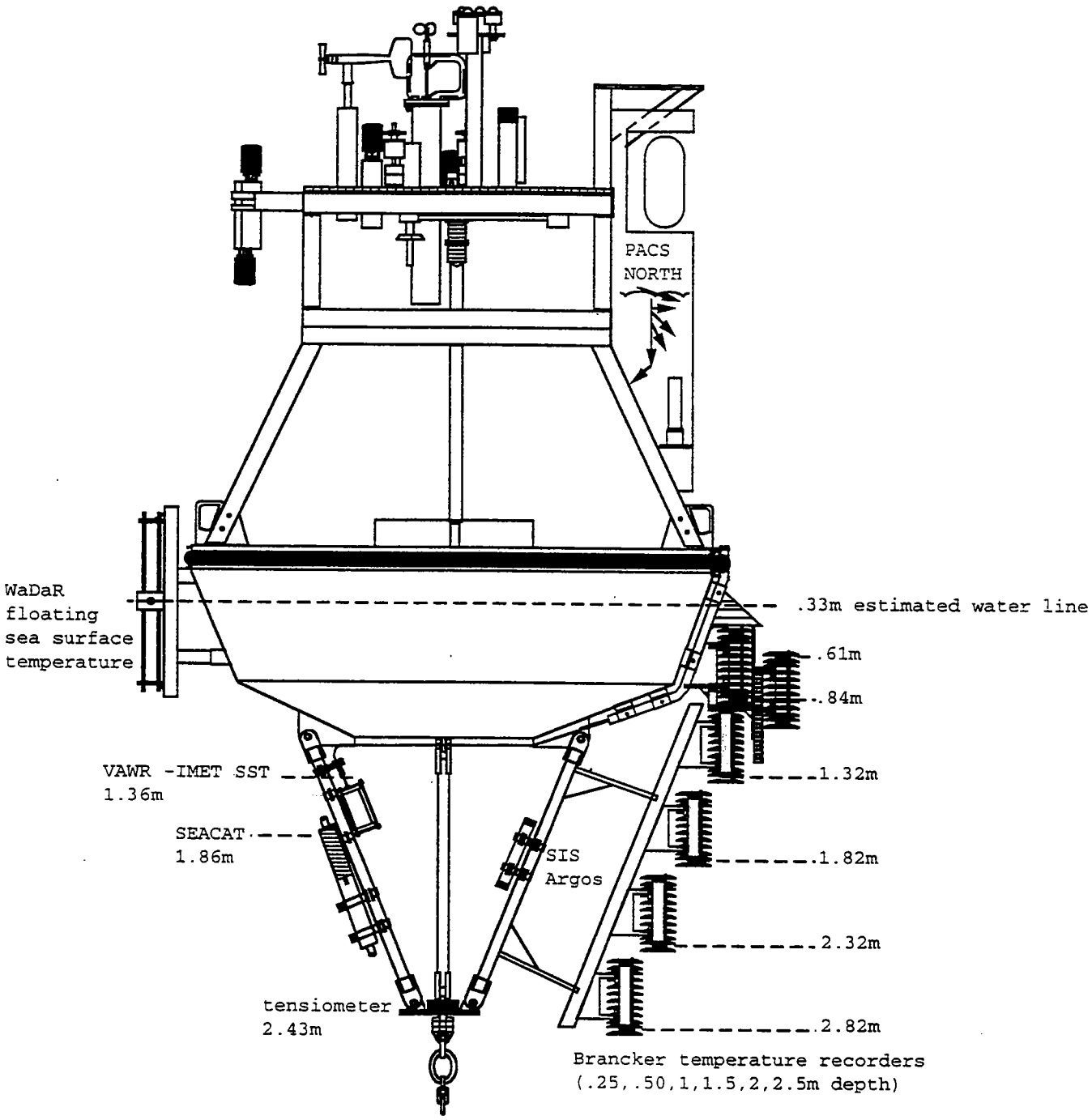


Figure 7: PACS 1 North discus buoy with tower and bridle instrumentation.

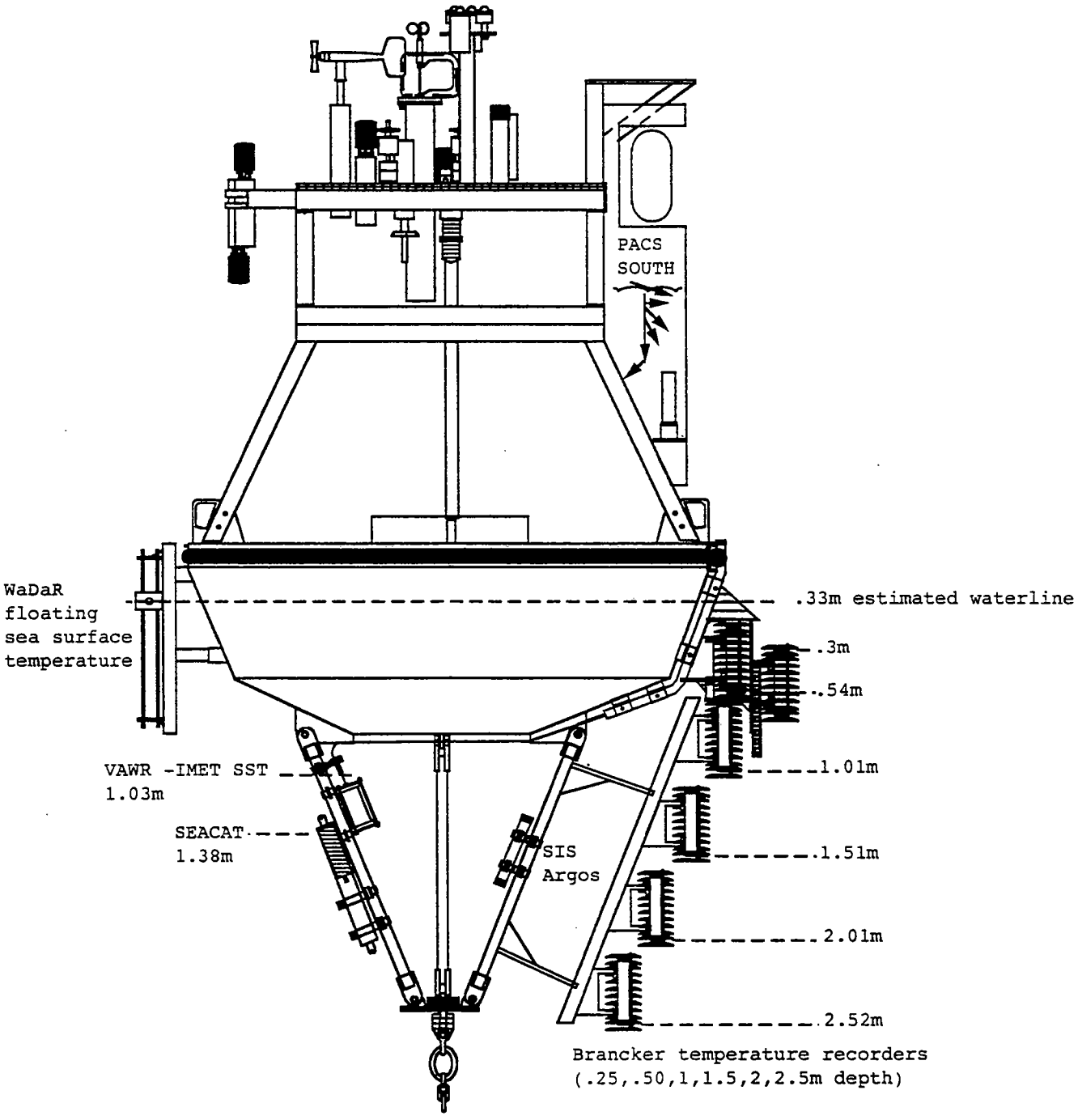


Figure 8: PACS 1 South discus buoy with tower and bridle instrumentation.

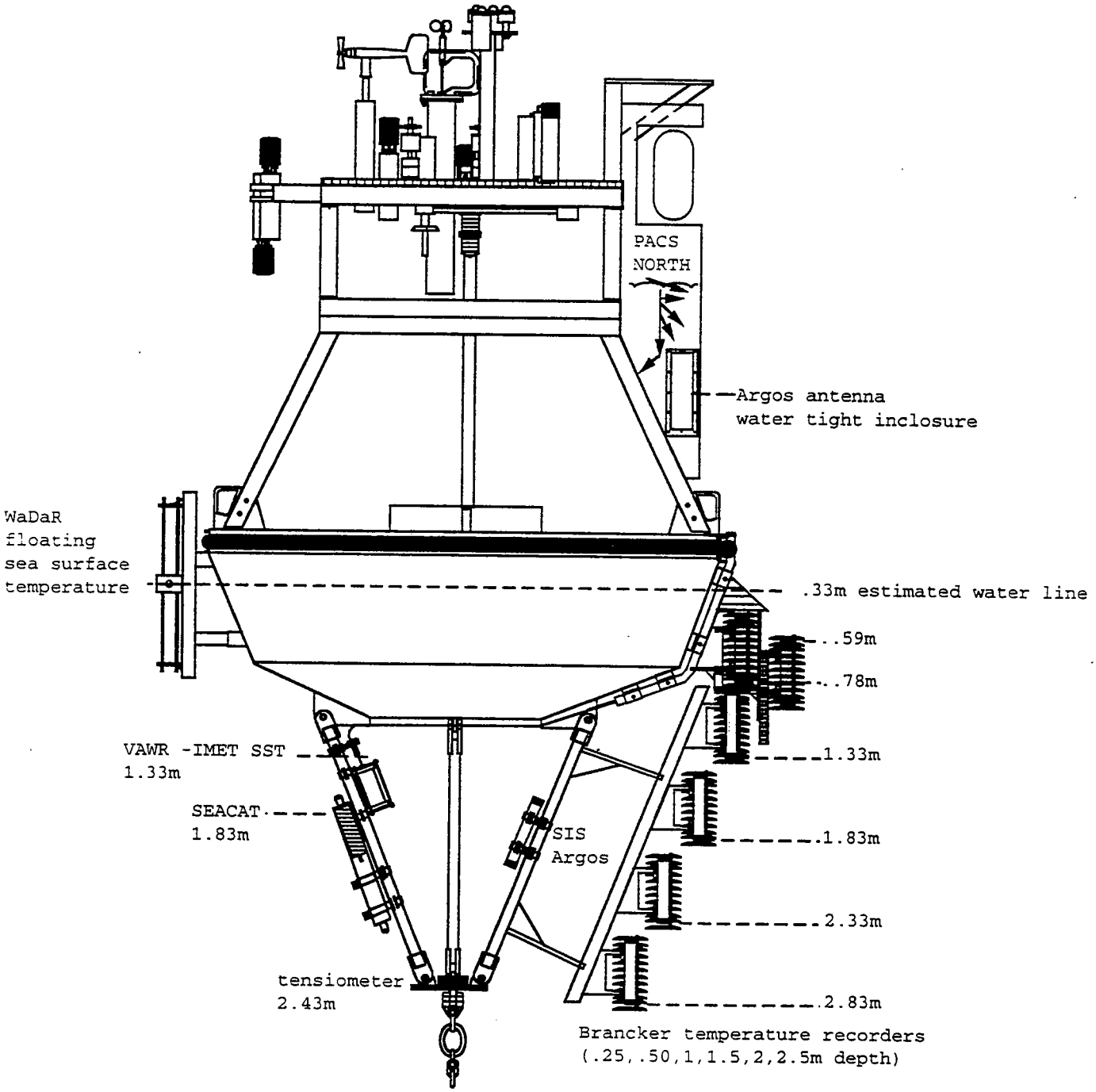


Figure 9: PACS 2 North discus buoy with tower and bridle instrumentation.

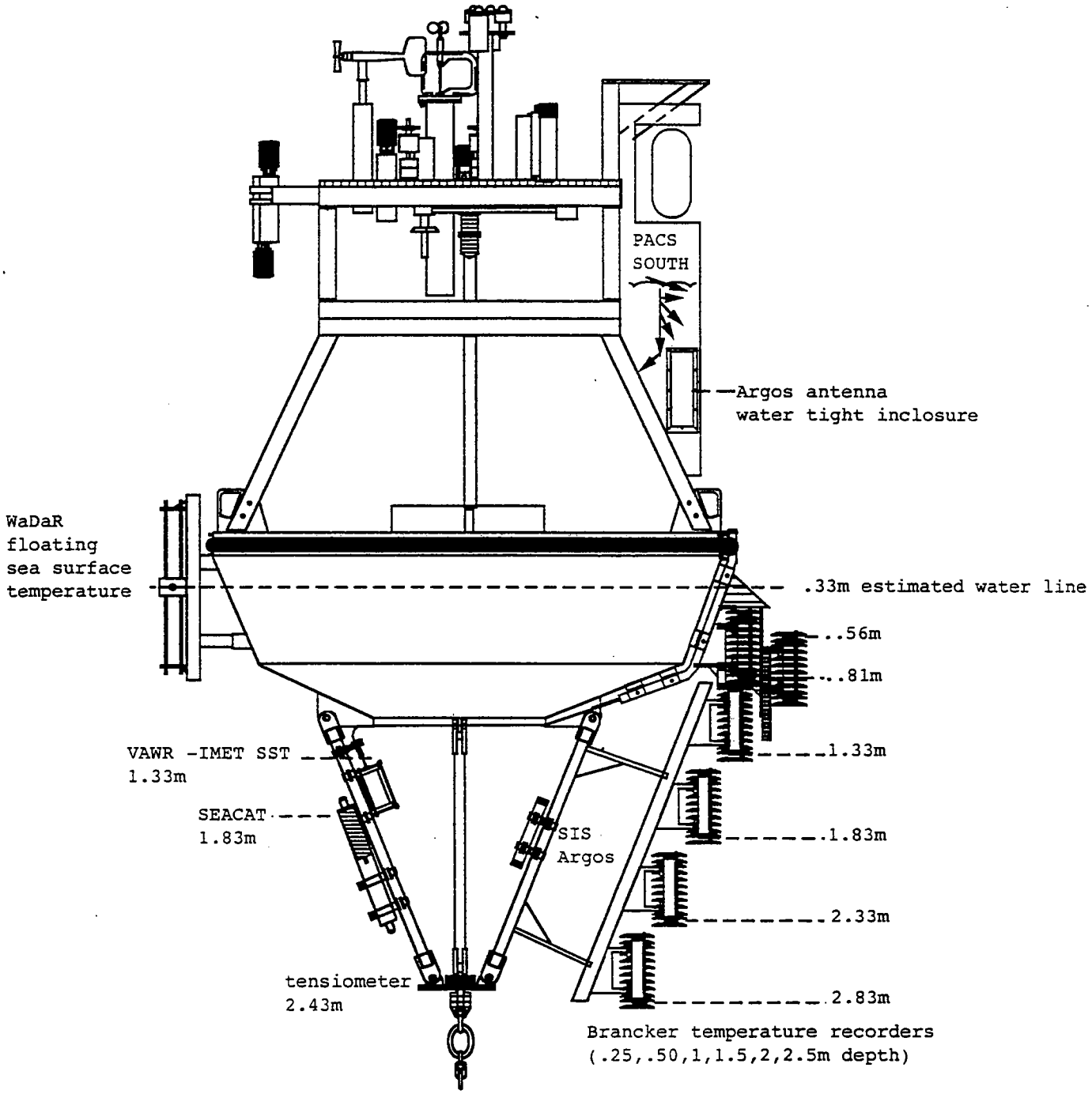


Figure 10: PACS 2 South discus buoy with tower and bridle instrumentation.

Shackles used on the WHOI moorings were shot peened to improve their fatigue endurance. Weldless endlinks were used based on their superior performance during fatigue testing. Vector measuring current meter (VMCM) cages were gussetted and welds redone to meet new specifications established during Arabian Sea cyclic fatigue testing. More information about the design effort and cyclic fatigue tests can be found in Trask, *et al.,* 1995; and Trask and Weller, 1996.

The PACS 1 North and South moorings each had two suites of meteorological sensors, 10 VMCMs, 17 temperature recorders, one of which was deployed in a small surface-following float, and five conductivity/temperature recorders. In addition, the PACS 1 North mooring had an acoustic rain gauge at a depth of 29 meters, and a mooring tension and buoy acceleration recorder. Additional instruments on the PACS 1 South mooring included: a CHLorophyll Absorption Meter (CHLAM) at 27.5 meters; a Sherman acoustic doppler current meter at 120 meters; and a Falmouth Scientific, Inc., 3D acoustic current meter at 130 meters.

The PACS 1 South instrumentation appeared in reasonably good condition at the time of recovery. The VMCMs had only minimal fouling in the form of slime and a few gooseneck barnacles. Some gooseneck barnacles that grew on either the propeller sensors or the supporting sting interfered with the free spinning of the propellers but not to such a degree that they prevented the propellers from spinning. In contrast the upper VMCMs on the PACS 1 North mooring were heavily fouled with gooseneck barnacles. The pressure cases of the upper VMCMs were encased with gooseneck barnacles to such a degree that the instrument case was not visible. The antifouling coatings used on the propeller assemblies definitely reduced the growth of barnacles; however, they still managed to grow on both the propellers and supporting sting. The barnacles interfered with the free spinning of propellers, but the propellers were able to spin.

The PACS 1 North mooring had another type of fouling, that caused by fishing net. Based on preliminary data records it appears that the fishing net became fouled with the mooring on or about October 14, 1997. Two VMCMs at 20 meters and 50 meters depth were completely fouled by the net. One SEACAT tension rod at 22.5 meters depth was wrapped in net and the instrument missing. The external communications connector on another SEACAT (at 32.5 meters depth) was broken off which resulted in a flooded instrument. The temperature pod at 25 meters was pulled upward along the wire until it met the wire termination. The acoustic rain gauge at 29 meters sustained some damage to the hydrophone protective cage. It appears that attempts were made to pull the net away from the mooring which resulted in instrument damage and loss.

The PACS 2 North buoy sustained other damage as well. Upon recovery the VAWR wind direction vane was missing, the vane cage was broken and one of the cups on the three-cup anemometer was missing. The VAWR relative humidity bracket was bent, as was the multiplate shield on the IMET relative humidity module. Traces of blue paint were found on the plates of the IMET relative humidity shield. A stand-alone precipitation sensor that was added to the buoy in August 1997 by the R/V *Ron Brown* was recovered with the funnel portion of the module missing. It should be noted that the damage described here did not occur during recovery of the buoy but at some time while the buoy was on station. The data from the VAWR indicates that the wind direction vane was lost on September 23, 1997. The floating sea-surface temperature bracket, which has three guide rods, was recovered with one of the rods bent. Unfortunately the temperature sensor was out of the water at the time the rod became bent; and, therefore, spent the remainder of the deployment in that position. One other interesting observation is that a 1/4-inch diameter line was found tied off to one of the buoy deck bales.

The instrument well of the PACS 1 North buoy was approximately two-thirds full of water at the time of recovery. The water, however, did not affect the performance of the instrumentation in the well while the buoy was moored on station. It became a problem following recovery when the buoy with its attached bridle was sitting on the deck of the ship at an angle. In that orientation the water seeped into the IMET battery junction box, resulting in the failure of the IMET system.

Each of the PACS 2 North and South moorings had two suites of meteorological instruments, 10 VMCMs, 17 temperature recorders with one mounted in a surface following float, and a mooring tension and buoy acceleration recorder. The PACS 2 moorings were outfitted with more conductivity/temperature instruments than the PACS 1 moorings. Each PACS 2 mooring had eight conductivity/temperature sensors. The PACS 2 South mooring had a bio-optical instrument at 27.5 meters which, along with other variables, made measurements of conductivity and temperature. The conductivity measurement made by the bio-optical instrument is one of eight made on the South mooring. A Sherman acoustic doppler current meter was also deployed at 120 meters on the PACS 2 South mooring

Each instrument used on the WHOI moorings was given a pre-cruise electronics check-out prior to being loaded onto the ship. Preparations for PACS 1 took place in Callao, Peru. Pre-cruise preparations for the second deployment were conducted at the University of Hawaii Marine Center located on Snug Harbor, Honolulu, Hawaii.

All of the instrumentation used on the WHOI moorings had some type of pre-deployment time mark applied. The meteorological systems had their short-wave radiation sensors black bagged for two record cycles. The VMCMs had their rotors spun. All of the temperature recorders were put in an ice bath for at least two record intervals. The times associated with these temperature spikes are recorded in each instrument's respective log book and appear in Appendix 3. The time marks can be used to verify the accuracy of the instrument's clock in data processing. Appendix 4 has a complete listing of all WHOI instrumentation deployed during PACS 1 and 2. For each instrument type the listing shows the instrument serial number, the mooring on which it was deployed and the corresponding depth.

Details about each type of instrument are provided below beginning with the meteorological instrumentation and then followed by the sub-surface instrumentation. Specific information about the instrumentation deployed during PACS 1 can be found in Way *et al.*, 1998.

1. Meteorological Instrumentation

The WHOI discus buoys were outfitted with two separate meteorological packages. One system was a Vector Averaging Wind Recorder (VAWR) which logged and telemetered data from eight meteorological sensors. The second meteorological data recording system called IMET (Improved METeorological measurements) logged data from nine meteorological sensors, and this data was also telemetered. On the PACS 1 deployment both buoys had a stand-alone, internally recording instrument that measured relative humidity and air temperature. In addition to the VAWR and IMET systems deployed on the PACS 2 buoys, there was also a stand-alone, internally recording instrument that measured precipitation as well as another that measured both relative humidity and air temperature. The relative humidity instrument is an improved version of the IMET relative humidity module in that it was self-powered and recorded its data internally. It was part of a family of instruments called VOS IMET which have been in use on Volunteer Operating Ships (VOS).

Figures 11 and 12 show a plan view layout of the meteorological instrumentation mounted on the PACS 1 and 2 WHOI discus buoys respectively. Tables 3 and 4 list the buoy-mounted instrumentation on the PACS 1 WHOI North and South buoys. The information listed includes sensor identification and sensor height with respect to the water line. Tables 5 and 6 provide the same information for the PACS 2 North and South buoys. The height of all buoy-mounted instrumentation is initially referenced to the buoy deck since the actual water line is never known until after deployment. At the time of recovery, if not sooner, the location of the water line is measured with respect to the buoy deck. In the case of the PACS 1 buoys the water line was measured to be .33 meters below the deck of the buoy. Since instrument loading and environmental conditions are expected to be similar for the PACS 2 deployment, the location of the water line is estimated to also be .33 meters below the deck. This will be checked when the moorings are recovered in the fall of 1998.

A wind direction sensor comparison test was conducted for both the PACS 2 South and North buoys in Woods Hole and at the University of Hawaii Marine Center. This was done to confirm that the compasses of each VAWR and IMET were in proper working order. The data from the direction comparison tests can be found in Appendix 5. The meteorological instruments are described in detail below.

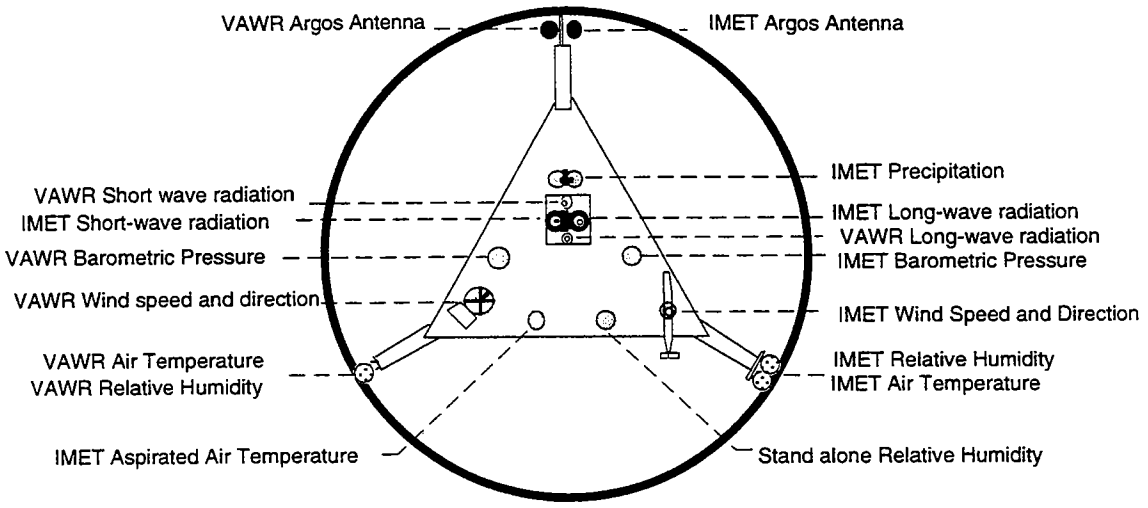
a. Vector Averaging Wind Recorder

One of the two meteorological units mounted on the WHOI three-meter diameter discus buoy was a Vector Averaging Wind Recorder (VAWR), which is configured to measure wind speed, wind direction, short-wave radiation, long-wave radiation, relative humidity, barometric pressure, air temperature, and sea surface temperature. Recording on a digital cassette, the VAWR wrote data to tape every 15.0 minutes. Table 7 shows the type of sensors used for the meteorological measurements and the sampling scheme. Data from the VAWR were telemetered via satellite back to WHOI through Service Argos. The VAWR Argos transmitter has three PTT ID numbers for data transmission, one of which is used for obtaining position information. The standard temperature range typically used in the VAWR is 0 to 30°C. This range for the PACS deployments was modified to be 0° to 35°C due to the expected high temperatures. The VAWR sea surface temperature (SST) sensor was mounted on the bridle at a depth of approximately one meter. A continuous length of cable was run from the VAWR to the buoy deck and then down to the bridle mounted SST sensor via an external aluminum pipe mounted on the side of the buoy to protect the cable. This method eliminated the need for multiple bulkhead connectors which can affect the temperature reading. Details of the VAWR configuration can be found in Trask *et al.*, 1995.

b. Improved METeorological System

The Improved METeorological (IMET) system for the PACS WHOI discus buoys consisted of nine IMET sensor modules and one Argos transmitter module to telemeter data via satellite back to WHOI through Service Argos. Table 8 details IMET sensor specifications. The following IMET modules types were deployed on the PACS discus buoys:

1. relative humidity with temperature
2. barometric pressure



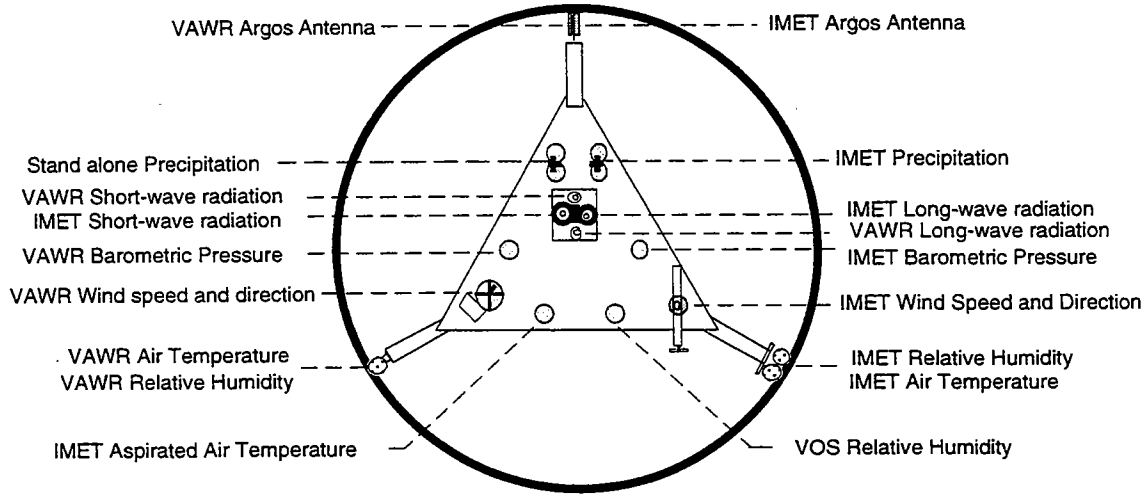


Figure 11: (top) PACS 1 meteorological instrument placement on buoy tower top.
Figure 12: (bottom) PACS 2 meteorological instrument placement on buoy tower top.