VII. Deployment

There will be three separate deployment and recovery stages. In the first operation we will deploy a Site-Measurement-String, recovering it during the same cruise. In the second operation, we will deploy a Prototype String and Monitor Buoy, recovering the Prototype String a few months later. In the final operation we will deploy 4 Array Strings, recovering them one year later.

VII.1.First test of scattering at site - 12/99

The goals for this test are:

1. determine optical properties of site
2. determine local currents at site.
3. determine acoustic properties at site .
4. determine surface properties at site
5. install acoustic net to mark site for later visits.
6. establish operating mode at sea - ship, personnel, logistics.

In this test we plan to drop a string consisting of anchor, batteries, housekeeping (current, power levels), a partially instrumented Monitor Module, an acoustic transceiver, and two optical instrument spheres or Site Modules, each containing a PMT, LED, CLK, and DAQ system. The Site-Measurement String will be at least 600m long, with the first optical instrument sphere 500 m above the anchor, and the second sphere 100m above that[1]. The String will have sufficient battery pack (1 kwh of Lithium Thionol Chloride batteries (LiR); see Appendix) to last 3 days at depth.

Each instrument sphere will have an LED that shines toward the opposite sphere and is pulsed in a known amplitude and duration pattern. The amplitude pattern is set so that an absorption length greater than 100m would allow each PMT to record each pulse from its opposite Site Module. If the attenuation length is shorter than 100m, then the lowest amplitude pulses will be attenuated away, with the relative frequency of these weaker pulses giving a clear measure of the attenuation length. If the scattering length is a significant fraction of the attenuation length, we will see pulses arriving "late" using our

[1] We would like to make these measurements as a function of distance separating the two optical mndules.

5ns sensitivity TDC. For a 100 m signal path, whose transit time is ~450ns, a 5ns sensitivity corresponds to a 1% change in path-length attributable to a scattering event.

The goal of this test is to determine the absorption length for blue light of the local water at the site. We expect the transmission curve to look as in Figure xx; the quantum efficiency of the PMT is shown in Figure xx. We will mark the site for later deployments using 4 acoustic transponders. We will use the acoustic link from the string to the ship to monitor string operation and location.

VII.2. Deploy single string for 3 months - March 2000 to June 2000

The goals for this deployment are:

1. Place a Prototype String at the site
2. Place the monitor buoy at the site
3. Determine the singles rates and coincidence levels in each cluster and in each node
4. Determine two-node coincidence rate

The purpose of this prototype string deployment is to measure the background in local coincidence mode and to show that we can construct and operate a two-node string at the site. This also tests our ability to recover a real string.

The total power per string will be as in the final instrument, or ~10 kwh. This will be provided by standard LiR battery pack consisting of ~150 DD cells.

We will communicate with this string in real time. A fiber to the string will allow continuous monitoring from the ship during deployment. We will use the acoustic link to command the Control Module to send disk and live data to receivers on the ship.

Once we have determined that the string is functioning properly we will leave it at the site for 3 months, monitoring it continuously through the acoustic link to the buoy.

We will then retrieve the string. We can extract the data immediately through the IDE port on each Cluster Control Module. The string will be returned to Berkeley for analysis of the effects of deployment.

VII.3.Deploy 4 strings - Sept 2000

The final array will consist of 4 strings. These are to be deployed at the site in a "square" of >300 m side length. Positioning of each string is not crucial, and an accuracy of 50-100 m is sufficient. The strings are deployed into the transponder array using feedback from the transponder array to fine-tune the "drop" position. Data from the string is continuously monitored at the surface through the fiber optic connection from each node.

VII.4. Recover Sept 2001

All 4 strings will be recovered after one year at depth. The data will be removed for off-line analysis. Strings will be returned to Berkeley for refurbishing and possible redeployment.

Vii.5.Mooring Design and Deployment Procedures

Plans call for the deployment of the NuBE mooring array some ten to 15 kilometers northeast of the island of St. Croix, US VI in approximately 4000 meters of water. The final array will consist of four 900 meter long sub-surface moorings arranged in a square pattern ~300 meters on a side. The technique that has been developed within the oceanographic community to handle these situations involves the lowering of the mooring on a cable, anchor first, to within a short distance above the bottom. The ship then navigates the mooring into position using an acoustic transponder network at which point the mooring is released to drop the last few tens of meters to the bottom. The major requirements for this system to work are reasonable weather and patience. A surface mooring will also be deployed in the vicinity of the sub-surface array to provide data telemetry to shore via acoustic links to the instrument packages on the moorings and by satellite and/or VHF radio links to land. The main mooring array will be deployed for about a year. The recovery will use standard procedures in which the moorings are acoustically commanded to drop their anchors so that they can float to the surface for retrieval. An expanded and detailed discussion of the mooring operations follows.

The sub-surface moorings will be of conventional design for deep water deployments. There will be two instrumented nodes on each mooring located 500 and 800 meters above the bottom and the whole mooring will extend 900 meters above the bottom. Each NuBE node consists of two clusters of six photo detectors and associated electronics and batteries separated vertically by 10 meters. The six photo detectors on each cluster will

be mounted on a frame and arranged to cover overlapping 2π sectors of the field. Each of the clusters will be an independent entity with its own internal power supply, data controllers, data recorders, and acoustic telemetry modules. The cluster frames will be mounted in line with the mooring and will carry the mooring tension . Mooring floatation will be provided by a total of five clusters of 17 inch glass balls which provide 400 lbs of buoyancy each and maximum mooring tension will be about 1,200 lbs. The mooring line itself will be 3/8 inch jacketed Kevlar cable (13,000 lb breaking strength). One hundred meters below the lower cluster there will be an acoustic release that will connect the mooring line to a 2500 lb anchor. Upon an acoustic command from the ship, the release will disconnect the mooring from the anchor so that the instruments can float to the surface during the recovery.

A schematic of the detector cluster design is shown in Figure __. The design requirements for the cluster are that it be able to provide, to the extent possible, unobstructed views in each of six orthogonal directions while also supporting battery and electronics packages. The design must also be able to attach to the mooring above and below and support a tension of 5,000 to 10,000 lbs. This high load derives from the deployment during which the instrument will have to support the 2,500 lb anchor under dynamic conditions. Maximum steady loads when the moorings is installed will be about 1,200 lbs. The basic design configuration is determined by this load carrying capability, the size of the 13 inch diameter Optical Modules, and the dimensions of the battery packs and Cluster Control Module. The power requirements to support the detectors, controllers, data recording and telemetry for each cluster for one year will be about 7.5 kwh (Table __). This power can be supplied by 112 DD Lithium primary batteries (20 amp-hrs at 3.4 volts each) which will be housed in a separate cylindrical 8" OD x 48" battery container. The central electronics package will be in a shorter cylinder of the same diameter. The separation of the various components of the system in this fashion provides a degree of protection in case of failure of any single element. The frame will be a welded structure comprised of 2 inch diameter schedule 80 stainless steel pipe. Preliminary design calculations indicate that the weight of each instrumented cluster will be about 700 lbs in air and 200 lbs in water. A total of 16 of these cluster frames will be needed for the deployment of the complete array.

The Acoustic Net

The deployment of the moorings will involve first the deployment of an acoustic net on the bottom with which we will be able to navigate the ship and mooring to approximately ≲5 meters. The net will consist of four acoustic transponders deployed on the bottom in a square pattern one water depth on a side ((4 km) which gives optimal range resolution for the ship and mooring as it is lowered. A minimum of three transponders is needed for resolving the three position coordinates, the fourth gives us redundancy and enhanced resolution through a least square solution to the now over-determined problem. We plan to use Benthos TR-6000 transducers on the bottom, Benthos 865 acoustic transponder/releases on the moorings and a Benthos DS-7000-4 four channel acoustic receiver on board ship to form the acoustic net and the Integrated Navigation System software to provide the three-dimensional position solutions.

The ship will be equipped with differential GPS (one second position accuracy of < 10 m) which will be used to preform the initial survey of the bottom acoustic net providing absolute positions for each of the bottom transponders. Once the bottom net has been precisely located, the acoustic net can then be used to determine the position, in three dimensions, of any other transponder that is lowered into the water. While this procedure is straight forward in theory, it takes experience to maximize the results. As a result, we will engage a contractor who does this routinely for the deep water oil industry to assist in the mooring deployment.

The actual deployment of the complete array will start with the deployment of the first mooring, anchor first, in the approximate center of the 4 km acoustic net. The mooring will be lowered on the ship's trawl wire to within a few tens of meters above the bottom at which point it will be released to drop to the bottom. The mooring's acoustic transponder/release will be located about 400 meters above the anchor. This height above the bottom provides a clear acoustic ray path to the transponder array. After the first mooring has been precisely located, the second mooring will be lowered over the side in the same manner as before but this time we will be constantly updating the position of the second mooring relative to the first. The ship will then proceed slowly to a predetermined location 300 meters from the first mooring. This procedure has been done in the past with much more complicated moorings and the main lesson learned is that the most important ingredient is patience. The deployment method for the third and fourth moorings is exactly the same although we will approach the array from a direction that will minimize the potential for fouling the moorings that have already been deployed.

When all four moorings have been deployed they will be carefully resurveyed to that the Cherenkov signal delays between the clusters can be properly interpreted.

The program protocol calls for the brief deployment of a complete mooring seven months before deploying the entire array. We will use this opportunity to not only test the hardware but also familiarize ourselves with the wind and current conditions of the site. We plan to explore the dynamics of towing the mooring, try out various techniques for placing the moorings precisely and finally to fine tune the deployment procedure.

In addition to the sub surface mooring array, there will be a surface buoy which will be used to provide near realtime telemetry to shore. This ability will enable us to monitor the condition of each of the nodes so that we can deal with any significant problems before they compromise the program. This ability also allows us to gather the data on a daily basis minimizing the impact of any potentially catastrophic problems with the insitu data loggers and also allowing the data processing to proceed continuously rather than wait until the moorings are recovered a year later. There are a number of options to dealing with surface moorings. The main difficulty here is the depth of water. There is a commercially available buoy system produced by the Woods Hole Group, Inc. which seems to be ideally suited for our application. The buoy was designed to collect meteorological and oceanographic data and telemeter it ashore via satellite and/or VHF radio links. The flexible design allows for tailoring the floatation to any situation. It also incorporates a complete internal data processing, recording and telemetry interface. The flexible processing system can be easily modified for our specific application in which we will install a multi-channel acoustic modem on the bottom of the buoy which can individually interrogate the sensor clusters. The retrieved data will be reformatted for packet radio or cell phone telemetry to shore. These systems allow two-way communication so that we will be able to trouble shoot some of the problems that may arise. A reduced data set made up primarily of house keeping and status information will also be sent to shore via ARGOS satellite. This system not only forwards the data to the user but also determines the location of the transmitter so that we can make sure that the buoy is on station.

The Ship

We plan to use one of the UNOLS vessels for this program, preferably the RV Seward Johnson from Harbor Branch Oceanographic Institution in Ft. Pierce, FL. This vessel is

equipped with the single most important piece of hardware for this program, a deep sea coring winch with the capability of lowering the moorings 4 km down. (I have to check on this.) The vessel has a large enough fantail to accomodate at least two complete sub-surface moorings on deck and is also equipped with all the navigation and acoustic transducers we will need. The ship has a large A-frame and enough internal lab space for working on the equipment. The ship has bow and stern thrusters and dynamic positioning abilities that will facilitate the close-in, low speed maneuvering we will need to position the moorings. Overall, we expect the deployment of the complete array to take about a week with at least one trip to our shore-side facilities on St Croix to reload.

Retrieval of the moorings is standard and quite straight forward. The acoustic releases individually will be commanded to release the anchor so that the mooring can rise to surface for recovery. The mooring line is then reeled onto a winch drum on the ship and the sensors, buoyancy packages, and acoustic transponders are broken out of the line as they come aboard. The retrieval of the array and surface buoy will take three to four days. Lastly, we plan to ship all the mooring components to and from St Croix in containers and to establish a shore-side facility with wharfage for the ship and an electronics lab to check out all the instruments well before the scheduled deployment time.