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PROGRESS REPORT TO OFFICE OF NAVAL RESEARCH

FOR CONTRACT NO: N00014-90-C-0123

TITLE: **Development of an Expendable Particle Sensor**

ITEM NO: 0001AH

DATE: **31 January 93**

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Principal Investigator

PROGRESS REPORT:

Development of an Expendable Particle Sensor

Sea Tech Inc.

Contract No. N00014-90-C-0123

Item No. 0001AH

INTRODUCTION:

This report addresses progress on the Phase II Development of the Expendable Particle Sensor (EPS) for the time period from December 1992 through January 1993. Work during this time period focused on both technical and administrative problems.

PROGRAM ADMINISTRATION:

The administrative problem is simply Sparton's lack of progress which has been an ongoing problem since the start of this project. No amount of technical assistance and encouragement or on the other hand, provocation including withholding of funds has caused this company to perform until recently. Sparton offers no plausible excuse for their lack of progress in the past.

The main question now is will Sparton perform in the future. A program review meeting with Sparton has been scheduled for mid-February to discuss the future of this project and both ONR and NRL will be advised regarding the results of this meeting.

As stated above, Sparton has recently shown some progress. Their progress report dated 25 January 1993 as well as their schedule for future progress is included in Enclosure 1.

Hydrodynamic Performance of the Proposed XOTD Expendable Probe

Based on the recent cancellation by NRL of the work planned to learn more about the hydrodynamic performance of the expendable probe, specifically to document boundary layer thickness and flow separation, it is now apparent that Sea Tech faces a major design decision. As vividly demonstrated by the expendable probe video data, the proposed expendable XOTD probe is hydrodynamically very unstable and because of this Sea Tech does not recommend it be used to house the light scattering sensor. Especially without any knowledge of boundary layer thickness or flow separation.

ONR must now decide one of two things, to go ahead with this project and solve the hydrodynamic problems at a later date or to terminate the project at this time. Sparton of Canada has indicated that they will not redesign the proposed XOTD expendable probe without additional funding.

Another option exists, that is to terminate the expendable and develop the non-expendable version of the light scattering sensor, this would only involve Sea Tech Inc. The excellent performance of the non-expendable version of the light scattering sensor has, since the start of this grant, been demonstrated by several investigators. The non-expendable version of the light scattering will satisfy most oceanic research requirements related to suspended particles since most researchers are only interested in relative particle concentration and are not interested in the optical properties of the particles. With the funds remaining in this grant a light scattering sensor could be developed that would cover the full range of suspended particle concentrations that can exist in natural waters and would in 95% of the cases replace the Sea Tech 25 cm, 10 cm and 5 cm transmissometer. The cost of the non-expendable light scattering sensor would be much lower than the cost of the existing transmissometers as well.

Sea Tech Inc. at this time prefers the option to develop the non-expendable version of the light scattering sensor. However, Sea Tech will proceed with the proposed development plan reluctantly is so directed by ONR knowing now that the performance of the light scattering sensor may be limited by the hydrodynamic characteristics of the proposed expendable probe.

Technical Progress at Sea Tech:

Thanks to Dr. John H. Morrow at Biospherical Instruments Inc. and Dr. Richard C. Murphy at The Cousteau Society who obtained both light transmission and light scattering data from a recent cruise on the Calypso to the Mekong delta in Vietnam. Figure 1 shows a typical profile in the Mekong delta using a Sea Tech transmissometer and a non-expendable light scattering sensor. Figure 2 shows the correlation between the beam attenuation coefficient and light scattering.

Figure 1 Calypso Mekong Expedition Data

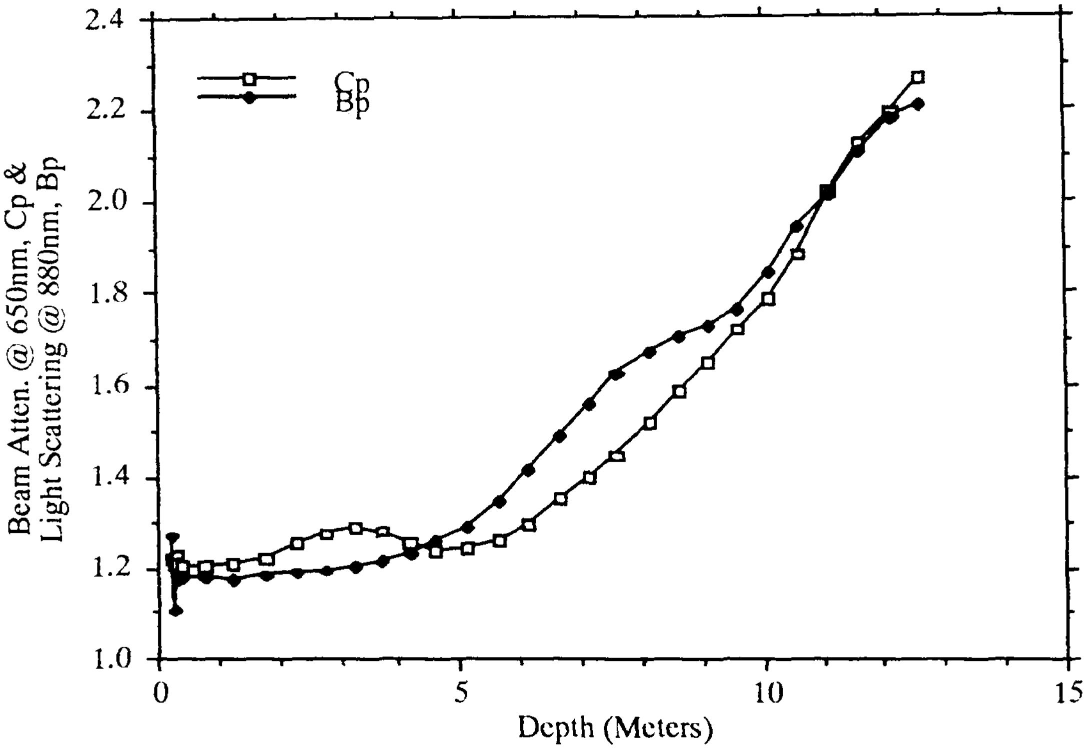


Figure 2 Calypso Mekong Expedition Data

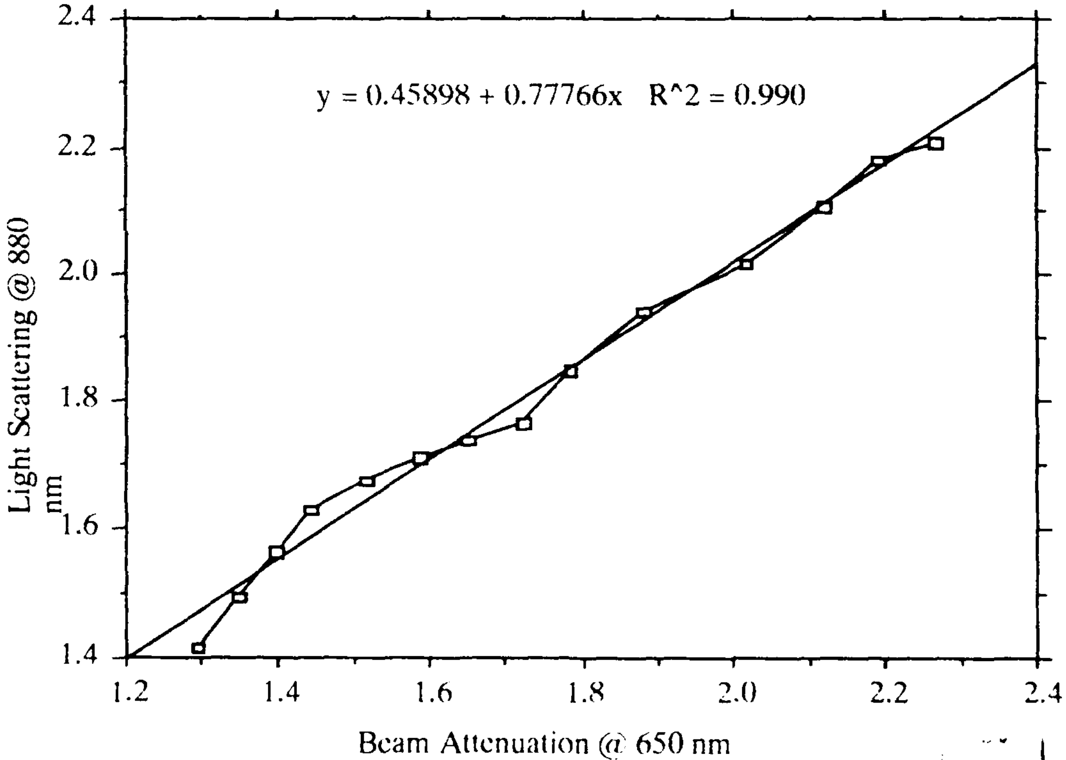
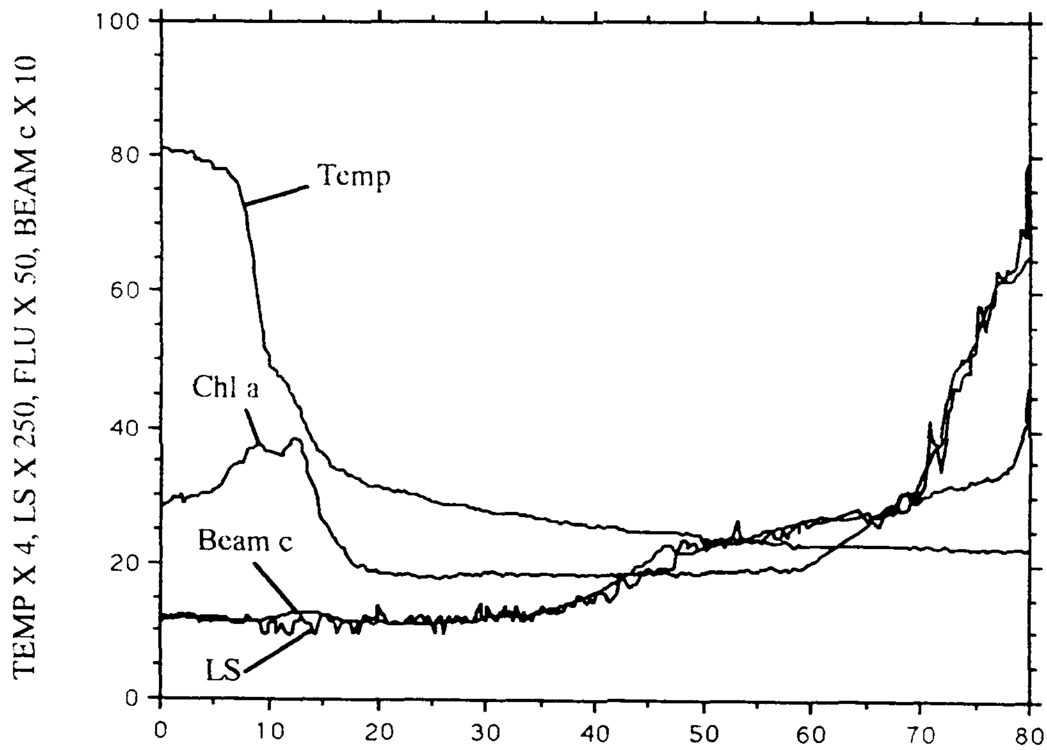


Figure 3 shows a profile taken in a fresh water reservoir near Sweet Home Oregon. This data was taken with the Sea Tech Optical Data Acquisition System. Light transmission at 660 nm, Chlorophyll a fluorescence, temperature and depth was measured on August 6, 1992 near the Green Peter dam in approximately 80 meters of water. The light transmission data was converted to beam attenuation for suspended particles, (Cp=Cm-Cw) and multiplied by a factor of 10, temperature data are multiplied by a factor of 20, Fluorometer data are multiplied by a factor 50 and Light scattering data are multiplied by a factor of 250. The beam attenuation and light scattering data is correlated very well indicating that the light scattering sensor will perform well for the measurement of suspended particle concentrations in water. Zero particles corresponds to zero volts output for the light scattering sensor unlike the transmissometer where the output is full scale. Because transmissometer full scale stability changes with temperatute, ~0.3%, the light scattering sensor will be more stable than the transmissometer for the measurement of very low particle concentrations in the ocean. It should be pointed out that no offset has been applied to the light scattering data indicating that zero signal represents nearly zero suspended particles.

Figure 3 Green Peter Dam, 8/6/92



Sensitive Volume Experiments

In order to optimize the light scattering sensor design Sea Tech has performed some laboratory experiments to study the sensitive volume for the scattering sensor. The information collected from these experiments will determine whether we can further increase the sensitivity of the light scattering sensors by optimizing the optical geometry as well as further define the sensitive volume for the sensor.

Low Concentrations

To determine the approximate sensitive volume of the scattering meter for low concentrations of suspended particulate material, we performed the following test. First, we measured the sensor's output in water with a low concentration of suspended clay particles. The sensor signal output was 3.5 Volts. We then isolated the contributions to this measurement from scattering in different portions of the sensitive volume by blocking, with black tape, sections of the emitter and detector windows as explained below, referring to Figure 3.

1. The output due to light scattering in area I was measured by taping over the inside half of the emitter window. The sensor output was 0.5 Volts, or about 14% of the total signal.

2. The output due to scattering in area VI was measured by taping over the inside half of the detector window. The sensor output was 0.3 Volts, or about 9% of the total signal.

3. The output due to scattering in area V was measured by taping over the outside 3/4 of the emitter window and the outside 3/4 of the detector window. The sensor output was 0.1 Volt, or about 3% of the total signal.

4. The output due to scattering in area II was measured by taping over the outside half and inside 1/4 of the emitter window, and the outside half and inside 1/4 of the detector window. The sensor output was 1.1 Volts, or about 31% of the total signal.

5. The output due to scattering in areas II and III combined was measured by taping over the outside half and the inside 1/4 of the emitter window. The output was 2.2 Volts, or about 63% of the total, so the output due to scattering in area III was 63%-31%, or 32% of the total signal.

6. The output due to scattering from areas II and IV combined was measured by taping over the outside half and inside 1/4 of the detector window. The output was 2.0 Volts, or about 57% of the total, so the output due to scattering in area IV is 57%-31%, or 26% of the total signal.

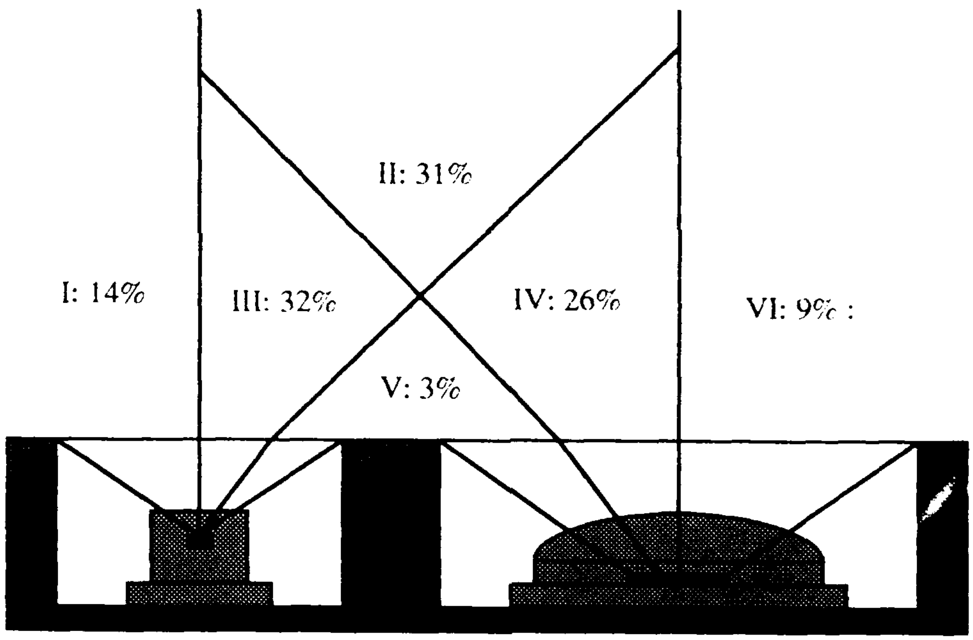


Figure 3

The sum of the contributions of each of the areas is 115% of the total signal output of the sensor. One explanation for this is that the emitter and detector both have finite areas, and thus the areas I-VI are not really as simply defined as shown in Figure 1. In reality, these areas overlap one another, and so the measurements of the contributions from these areas included some scattered energy that was counted twice. Also, these measurements were relatively crude, and therefore we expected some error in the measurements.

What is clear from this test is that the sensor configured as shown in Figure 1 measures predominantly backscattered light at low particle concentrations, not forward scattered light as we had previously hypothesized.

High Concentrations

Tests were also performed on the sensor in high particle concentrations (on the order of 1 g/l). In a very simple but informative test, we taped over the inside half of the emitter window and the inside half of the detector window and immersed the sensor in the high concentration solution. When we did this in low concentrations, we received no scattered light since single scattered light was prevented from reaching the detector. In the high concentration solution, however, the output of the taped sensor was almost 50% of its output without the tape. Thus, it was clear that multiple scattering was the dominant mechanism at high concentrations.

In another test in the high particle concentration solution, we taped the wall of the beaker with black electrical tape to reduce reflections, and then placed the sensor near the wall to see if its output changed. We found that when the sensor was as close as 5 mm from the beaker wall, its output changed less than 20% from its output in the center of the beaker . Thus, at high concentrations the sensitive volume is very close to the sensor surface and it measures predominantly multiple scattered light.

Conclusions:

Based on the above results it appears that the sensor geometry is not optimum since only 3% of the signal is due to forward scattered light. Further work will be done to verify this conclusion. As designed the XOTD sensor predominately measures backscattered light for low concentrations and multiple scattered light for high concentrations.

Enclosure 1

INTRODUCTION:

This report provides a detailed account of Sparton of Canada (SOC) activity over the period November 1992 up to and including January 1993 for the development of an expendable ship and air launched optical scattering probe/buoy.

The initial section of this report provide a short summary of work in each major area of the development program. More detail is found by referencing to the Appendices later in the report.

1. XOTD PROBE DESIGN ELECTRICAL

Progress was made on the electrical design of the (A)XOTD probe over the reporting period. Tests of the power supply circuitry including the battery, sea switch and voltage inverter were conducted. A SMT PCB layout was completed and the SMT boards are being built and tested. Thermistor dissipation measurements were also made.

Battery

Initial test show that a STD 9 volt alkaline batteries can meet the XOTD power requirements after a 2 year storage period. The 9 volt batteries are widely used, economical and readily available. The 9 volt batteries; however, are more difficult to pack into the XOTD probe than an assembly of A76 cells. But the mechanical XOTD probe design was done to fit the worst case (the 9 volt batteries) so now either battery type can be used.

Several battery types were tested. After accelerated aging (stored at 85 °C for 11.5 days to simulate 5 years) and under cold start (-20 °C) the EN22 Eveready 9 volt battery read 7.8 volts after driving a 75 ohm load for 30 seconds. The EN22 9V alkaline battery should meet the requirements of the XOTD program. A complete description of the battery testing and test results is in Appendix 1.

A preliminary battery pressure test has been conducted. The initial test showed that batteries with minimal potting support (soft compound to test worst case) started to fail at about 450 to 500 meters (675 to 750 PSI). Hence care must be taken when potting the battery. A plot of the initial test results are in Appendix 1. Further battery pressure tests will be conducted.

Sea Switch Testing

The sea switch was tested for leakage (off state), for sensitivity to resistance between sea water contacts (turn on) and for the changes in V-DS versus temperature. The D-S voltage drop for the VP01 at 100 mA of current was about 0.64 volts. The D-S voltage drop for the VN01 at 20 milli amps was about 0.08 volts. The test results are in Appendix 2.

Tests have also been conducted on a CCT which uses as single 9 volt battery and an LMC7660 voltage inverter. Preliminary tests with the SOC processor showed that an XOTD powered by 2 batteries through the sea switch and +/- 5 volt regulators had similar resolution/noise performance as one supplied by as single 9 volt battery through the switch with as LMC7660 and +/- 5 volt regulators. The preliminary test results for this CCT are in Appendix 2.

SMT Layout and BOM

A SMT layout of the XOTD probe CCT has been completed, the new boards have arrived and are being populated and tested.

Appendix 3 shows the schematic and layout drawings of the XOTD CCT as well as a preliminary BOM. Space has been included on the PCB so that a voltage reference can be used with the temperature circuit as necessary. Space has also been left for pots which may be used during calibration as necessary.

The circuit is on two separate boards; the sensor board and the main CCT board. The sensor board contains the optical coupler, the LEDs, the photo detector, op-amp U3. The boards are connected by a 10 pin connector.

The centre to centre spacing between LED and detector is 0.50 inches with a 0.1 inch thick light block which with our geometry gives the 60 deg angle from normal through centre of detector and LEDs to the edge of light block. There is a second set of holes with a spacing of 0.66 inches.

The cct layout was done so that either two batteries or a single battery and an LMC7660 can be used to power the CCT.

The BOM is preliminary and includes some redundancies. Ie. it includes both two batteries and the LMC7660. It also includes a voltage reference and potentiometers which may not be used in the final product.

Telemetry

The spool transfer characteristics were modeled and measured for the 500 meter XOTD and AXOTD. A 500 M XOTD fully wound (in air) will have about 20 dB of line losses at 1500 Hz. A 500 M XOTD fully despooled (in water) will have about 32 dB of line losses at 1500 Hz. The XOTD CCT will produce a 10 volt P-P signal (about 20 dBv re 1v P-P) so the XOTD output signal will range from about 0 dBv re 1 v P-P (spooled in air) to about -12 dBv re 1v P-P (completely despooled in water).

The processor XOTD channel can take signals as large as about 26 dBv re 1 v P-P (20 V P-P) without clipping. The maximum signal from the XOTD (500 Hz spooled in air) will be about 12 dBv re 1v P-P. Thus an instrumentation amp with about 14 dB gain could be used at the input to the processor XOTD channel. At 0 and 14 dB gain the minimum signal at the comparator will be about 0.25 V and 1.25 V P-P respectively.

Appendix 4 contains the spool test data.

Thermistor Dissipation

The dissipation of the 5K3A19P thermistor was measured in air and in a circulating bath. The results are in Appendix 5.

2. XOTD PROBE DESIGN MECHANICAL

The mechanical XOTD probe design criteria was:

- Keep the probe outside diameter the same as that of the XBT
- Place the optical sensor as close to the nose weight as possible.
- Fit 2 standard 9 volt alkaline cells
- Fit SMT XOTD PCB
- Maintain same flow tube area through area through the probe as the XBT.
- Allow for a simple and practical assembly procedure

To meet the above criteria the preliminary mechanical design uses a dual flow tube concept. The two symmetrically spaced flow tubes have the same total area for water flow as the XBT nose weight with the thermistor in position.

The optical sensor assembly contains both the optical sensor and the sea switch contacts. It was designed so it can be assembled, potted and then connected to the XOTD SMT PCB and to the thermistor. This whole assembly can then be slid neatly into a cut away section at the front of the XBT-5 extender tube.

The two key completely new parts are the flow plate and optical sensor holder. Machined samples of both these parts have been made and complete mechanical XOTD models have been built and are undergoing laboratory testing. A mould kit which can be used to make epoxy parts is being looked into as a cost effective way to make samples of the new parts for engineering tests. Cost estimates for hard tooling for the new parts have been obtained, however hard tooling for the new parts will not be developed until the parts have been approved by Sea Tech and field tested.

The models and concept drawings show an XCTD type tail fin as per Sea Tech's request.

Appendix 6 contains drawings of the latest mechanical design concepts and a preliminary mechanical BOM.

3. AXOTD DESIGN

AXOTD ELECTRICAL

The AXOTD will use the same probe as the XOTD. An separate PCB will be used to interface the XOTD signal from the probe to the AXBT surface electronics.

A SMT interface PCB containing the Sea Tech line RX CCT (modified for single supply operation) has been assembled and tested. Noise floor and transfer function measurements of the AXOTD system through the transmitter and a receiver have also been made. A schematic of the interface CCT and plots of the measurements are presented in Appendix 7. The AXOTD probe signal was measured with the SOC processor through the RF link. The single snapshot (about 13 frames) VCC and GND channel noise was within about 0.01%. Noise on signals measured through the RF link was about the same as on signals measured directly from the probe; the RF link did not cause an increase in noise. The measurments are presented in Appendix 7.

MECHANICAL AXBT vs AXOTD Configuration

The two configurations are graphically illustrated in the diagram titled `**Comparison of AXBT to AXOTD**' (APPENDIX 6).

The AXOTD consists of many standard parts used in an AXBT.

The AXBT components utilized are:

- parachute/decelerator sub assembly
- surface electronics assembly
- blow molded outer sonobuoy housing
- ballast weight container

The XOTD probe replaces the normal AXBT sensor. The XOTD probe is longer therefore the bulkhead that the surface assembly normally rests on will be moved to a lower location within the buoy. The bulkhead will be rigidly attached to the outer housing walls.

A long plastic tube will act as a structural support between the surface housing and the bulkhead. This tube will bear all of the inertia forces developed when the buoy impacts the water and pass these forces onto the bulkhead plate. The tube also acts a stowage location for the probe restricting its motion in lateral directions.

Two additional changes must be made to the AXOTD to insure that it has the same weight and center of gravity as the AXBT:

1. The components used to adapt the AXBT to the AXODT configuration have a summed weight which is slightly greater then all of the components that they replace from the AXBT. This means that the ballast weight located in the bottom portion of the buoy must be reduced to compensate for the additional component weight.

2.In order to retain an identical center of gravity, the weight distribution must be altered. This redistribution occurs by further reducing approximately 0.63 lbs from the newly defined ballast weight and adding it to the newly located bulkhead. The bulkhead can be made heavier by using thicker steel for the plates.

All of these configuration changes will result in a buoy with AXOTD sensor characteristics while maintaining AXBT flight characteristics.

4. XOTD PROCESSOR DEVELOPMENT

Diagnostics software for the SOC XOTD processor card has been developed. The counting accuracy and resolution of the processor card was assessed by measuring a continuous signal from a generator. The noise and resolution of the processor was also measured for the TDM XOTD signal. It was found that the processor measured the XOTD signal as well as it did that from the generator. The noise of the signal measured from the generator was only about 4 times the resolution expected from counting with a 2 MHz E-clock. It is not known whether this noise was actually in the signal being measured or whether it was due to the processor measurement technique.

A description of the diagnostics software and a summary of the preliminary processor test results is presented in Appendix 8.

5. SCHEDULE AND CRITICAL MILESTONES

An Updated schedule is provided in Appendix 9. It shows the upcoming SOC/Sea Tech review meeting scheduled in February, 93. An engineering field test is scheduled for beginning of March, 93 and a demonstration of 12 AXOTDs is scheduled for the middle of April, 1993, which will meet requirements stated by NRL.

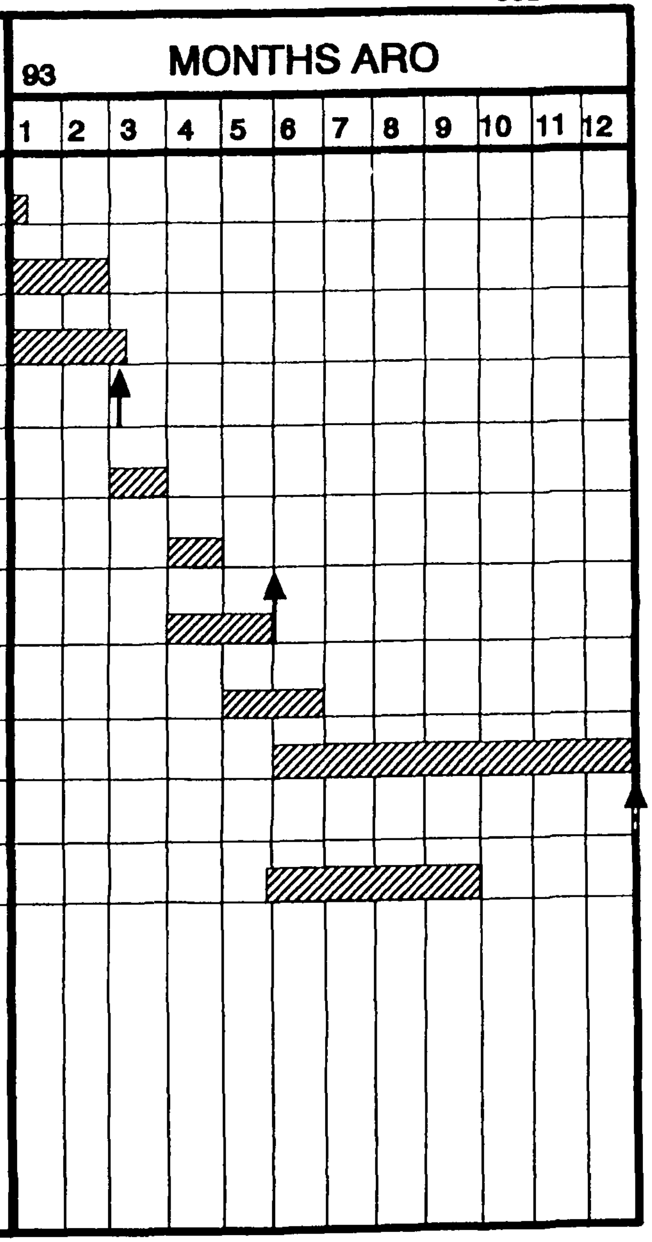
APPENDIX 9

XOTD/AXOTD PROCESSOR PROGRAM SCHEDULE
(RECOVERY PLAN)

Date: 26 January 1993

Job 8007

#	TASK DESCRIPTION
1	Review Design
2	Hardware Design Build Test
3	Software Design Debug Test
4	Field Test
5	Design Changes
6	New PCB
7	Build & Test
8	Software Mods
9	Build Production Proto Type
10	Field Test
11	Production Test Equipment



Date: 26 January 1993

XOTD/AXOTD PROGRAM SCHEDULE (RECOVERY PLAN)

Job 8007

#	TASK DESCRIPTION	93: 1	2	3	4	5	6	7	8	9	10	11	12	94: 1	2
1	Probe Design Phase														
2	Build Proto Probes														
3	Interface to VHF TX														
4	Design Review (SeaTech, SOC)														
5	Eval: Range, Accuracy, SNR, Resolution														
6	Develop Proto Mfg Capability														
7	Engineering Field Test														
8	AXOTD Field Demonstration														
9	Design Review (SeaTech, SOC, ONR, NOARL)														
10	Build Test Eval. 24 XOTD 24 AXOTD				BUILD		T	EVAL							
11	Design Review (SeaTech, SOC)														
12	Redesign & Test														
13	Develop Research Production Mfg. Capabilities														
14	Design Review (SeaTech, SOC, ONR, NOARL)														
15	Build Test Eval. 72 XOTD 48 AXOTD										BUILD		T	EVAL	
16	Final Report														
17	Monthly Reports														