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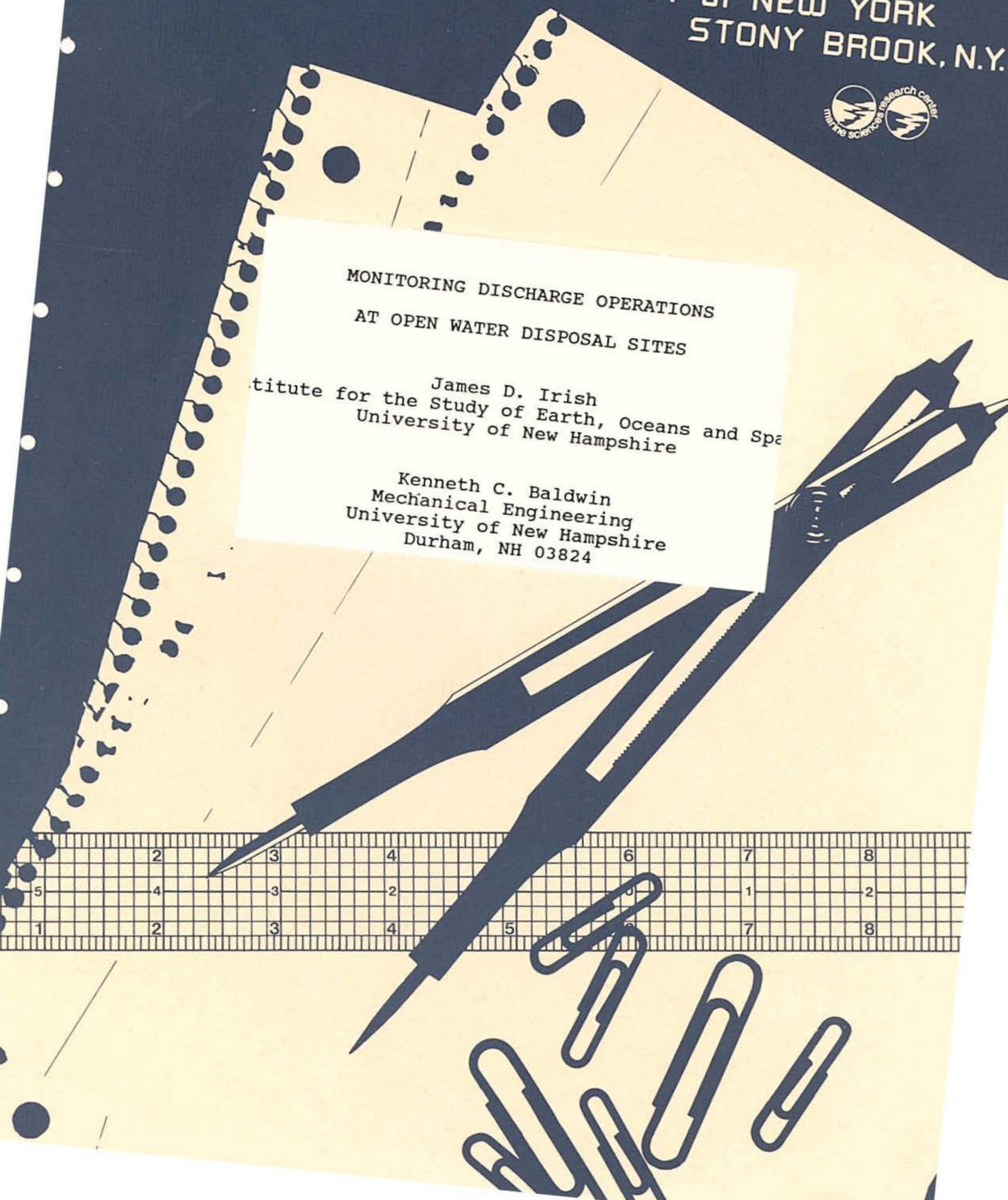

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Introduction

Every year over 210 million metric tons of sediment are dredged from navigable waterways in the United States (U.S. Congress, Office of Technology Assessment, 1987). Eighty to ninety percent of this material is discharged at open water disposal sites intended to contain the material. It has been demonstrated repeatedly that compact deposits of dredged sediment can be created by conventional disposal techniques; more than 95% of the dredged sediment can be placed in a small area by carefully controlling the point of discharge. Since the diameter of the resulting deposit may be only four or five times the length of the barges or hopper dredges used in the operation, accurate position is critical to successful containment. Taut-wire buoys, with a watch circle of as little as 1 meter, have been used to mark the discharge point and barges have been required to be held stationary at the buoy as the dredged sediment is released.

About 30% of dredged sediment is contaminated to some extent (Bishop, 1983) and additional precautions are often taken to insure containment of this material at open water disposal sites. To prevent these contaminates from reaching the water column, covering, or capping, of contaminated dredge sediment deposits on the disposal site has become routine. This techniques requires even more careful design of the discharge operation to minimize the area covered by the deposit of contaminated dredged sediment and, therefore, to maximize the efficiency of the capping operation.

An even greater degree of containment can be achieved by the subaqueous burial of dredged sediment in pits on the sea floor. This disposal option has been recommended as a feasible alternative for the disposal of large quantities of dredged sediment (Connor, et al., 1979). A small pilot project has been done in the Duwamish Waterway and comprehensive studies have been done to implement this disposal alternative in New York Harbor (Bokuniewicz, et al., 1986).

As disposal operations become more deliberate, monitoring plans must develop simultaneously to insure the enforcement of restrictions on the time and location of discharges, the growth of the deposit of dredged sediment on the disposal site, and the uncontrolled escape from the disposal site of material that may have unacceptable environmental effects. Monitoring the operation at a pit disposal site may be more critical than it is at other open water sites for four reasons:

1. Pit disposal is a new technique,
2. The site is likely to be smaller, therefore, more control must be exercised over the discharges.
3. The potentially most suitable sites are in shallow, protected waters close to shore,
4. Contaminated material will be involved.

During the open-water discharge of dredged sediment, more than 95% of the material rapidly reaches the sea floor and spreads across the bottom in a dense (~ 1000 mg/l) slurry one or two meters thick (Bokuniewicz, 1985). This can easily be detected with a transmissometer, nephelometer, reflectometer or a standard 200 kHz fathometer; the interface between the spreading slurry and the overlying water is sharp (Bokeniewicz, 1985, Proni and Hansen, 1981). The cloud of suspended sediment collapses to the sea floor within about 30 minutes and 200 meters from the discharge point. Observations made to monitor the spread of the slurry can be as simple as looking for a boundary violation or as complex as fully monitoring the suspended sediment and distribution.

Any monitoring system should be as automated as possible without becoming unduly complicated and it should provide the required information promptly and as directly as possible, that is, without requiring a large amount of additional analysis to obtain the measurements. As a result, in situ, real-time observations would be most useful. In this report we discuss the feasibility of a real-time, in situ instrument system to monitor one important element of the discharge operation --- the spread of the dredged sediment released during each discharge. Permanent bottom-mounted acoustic devices could also serve as beacons to locate each discharge location or orient shipboard surveys.

The remainder of this paper discusses monitoring methods and concepts for in situ instrumentation. We first review packaging of the components on various types of instrument frames. The acoustic command systems include both release capability and acoustic data telemetry. An intelligent data logging system processes data and uses a knowledge based system approach to increase the benefits of in situ instrumentation. Next various sensors and sensing options are discussed in terms of their relationship to the monitoring process. Finally, we present a recommended development which shows an orderly evolution of concepts, testing and deployments to produce in situ bottom-mounted instruments for monitoring dredge spoil discharge operations. Although many of the components of the conceptual system presented here have been developed in various laboratories and research centers around the country, the proposed configurations and uses of the hardware and software are new and innovative.

Monitoring Methods and Instrumentation

Remote instrumentation systems mounted on the sea floor have several advantages in monitoring oceanographic processes. These instruments can use nearly as wide a variety of sensors as packages lowered from ships to make point measurements. The instruments are not as subject to damage as systems lowered or towed from a ship. The system can remain in one place on the sea floor for several months duration, thus obtaining a continuous record, 24 hours a day, of what is happening at the site. A remote instrument is a "neutral" observer which does not necessarily require any action by the barge and tug or by an onboard observer. The instrumentation can record data internally as well as acoustically telemetering processed information to a ship or buoy, for study or relay back to shore by radio.

Possible disadvantages include the increased cost of power which is not supplied by the ship, but must be carried in the instrument. A telemetry link which allows the data to be monitored in near real-time increases the cost. This is offset by the reduced costs of not having to send sampling boats out with every barge load, and the increased information from continuous monitoring. We believe that bottom mounted instruments will be a benefit in disposal site monitoring and should be developed and tested. The benefits will allow safer, more efficient management of the site.

The remote instrument package can be configured with various sensors, data logging and processing electronics with capabilities matched to the sensors and site, and communication hardware to telemeter data back to shore. Below several options are outlined for bottom instrumentation from simple optical monitors to complex acoustic systems. We first discuss the physical configuration and data system, then discuss sensors and sensor options is a separate section following.

Instrument frame:

An aluminum, fiberglas, other plastic or composite material frame would unite all components of the instrumentation system into one easily handled package. Figure 1 shows an a simple instrument which has been configured with bottom pressure, temperature, and conductivity sensors, internal batteries and cassette recorder (Brown, 1976). These instruments have been deployed by the University of New Hampshire (UNH) in shelf regions since 1976. It is small, light weight and well suited to

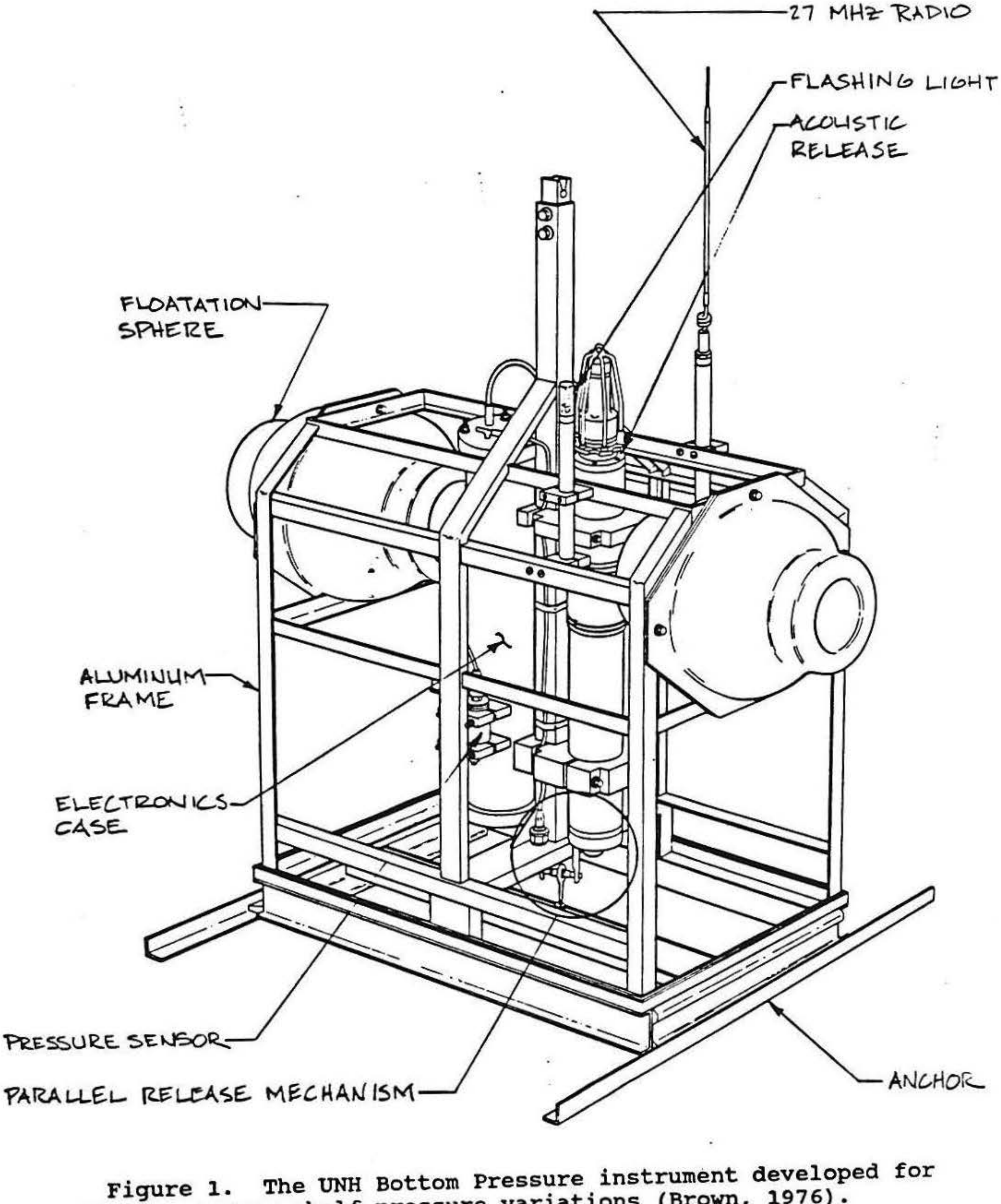


Figure 1. The UNH Bottom Pressure instrument developed for monitoring across shelf pressure variations (Brown, 1976).

simple monitoring applications requiring low power, no in situ data processing or compression, few sensors and low sampling rates.

A more complicated and powerful instrument system is shown in Figure 2. It has the capability of carrying more power, a greater number of sensors, an intelligent data and acoustic telemetry systems. These instruments have been deployed in shelf regions since 1980 (Irish, Woodbury and Lacoursiere, 1984). This package can easily be adapted to disposal-site monitoring by adding an acoustic sensor at the top where the moored array has been attached in the past. The instrument has a microprocessor controlled data logger with sufficient power for sophisticated acoustic sensors. It also has an acoustic release and a separate acoustic telemetry pinger.

The instrumentation is held firmly on the sea floor by a metal or concrete anchor to which the instrument is fastened. Figure 1 shows a simple metal frame anchor with several lengths of railroad rail as the main ballast. The instrument in figure 2 requires a larger anchor with a scrap railroad wheel as the main part of the anchor. An acoustically commanded release separates the instrument package from the anchor which is left behind. Flotation, provided by glass balls or metal spheres bolted to the instrument frame, float the instrument package to the surface for recovery. The cost of a frame with flotation is $1,000 to $2,000 depending on the size and amount of flotation required. An alternate method of recovery would be to use divers to connect a line to the instrument.

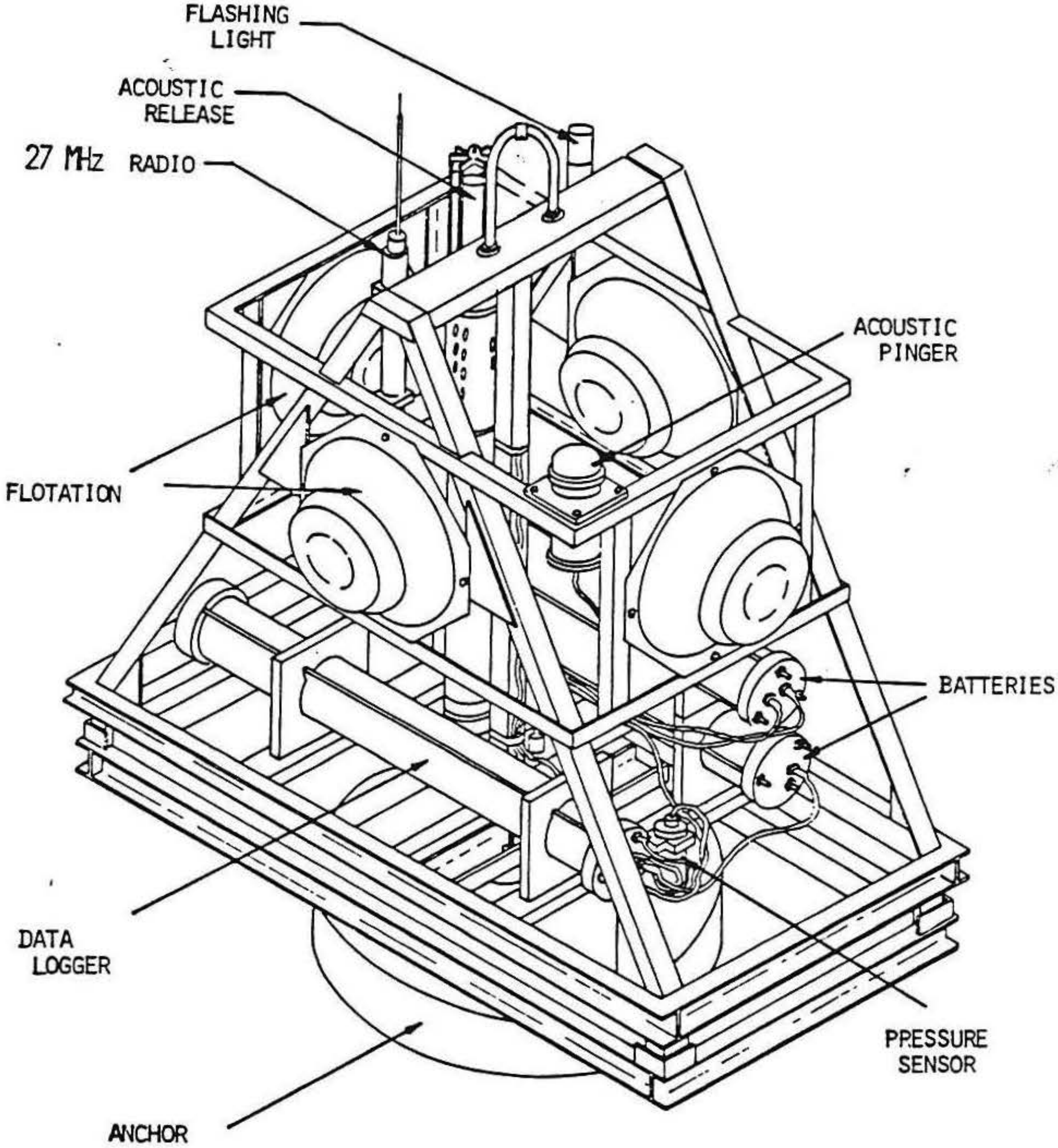


Figure 2. The UNH microprocessor controlled, conditionally sampling, bottom mounted density array instrumentation (Irish, et. al., 1982) as deployed on the California Shelf in CODE (The Code Group, 1983) in 1980 and 1981. A modified form of this held a Doppler acoustic profiler during CODE and in the Strait of Gibraltar (Pettigrew, et. al. 1986).

Another method of deployment is diver installation of the bottom package on an anchor, pipe or other mount which is secured to the sea floor in a known position. This has the advantage that any required orientation of the instrumentation system and sensor package (i.e. alignment of a horizontal acoustic beam) could be done at this time. Diver installation on a previously deployed and surveyed mount has the advantage that repeated deployments of a single instrumentation system are relative to the same reference orientation and depth which allow the data from multiple deployments to be combined into a single record. The fixed mount makes it easier to use the system as a reference for a shipboard survey program. The disadvantage is the added cost and danger of putting divers in the water.

In this concept, the exact sensors required for a particular application are mounted on the frame in an appropriate exposure. Acoustic sensors require an unprotected position on the instrument, i.e. on top of the frame in Figure 2. Optical transmissometers are attached to the electronics pressure vessel mounted inside the instrument frame such as shown in Figure 1. Downward looking acoustic sensors require a more open frame than shown in Figures 1 and 2. Figure 3 shows a typical open frame (Butman, and Folger, 1978) which is deployed for sediment transport measurements. This instrument has the advantage of an open frame which does not contaminate the observations, but it is more prone to damage by fishing, waves and currents. Also note that the recovery system releases a float which brings a line to the surface which is used to retrieve the instrument. This

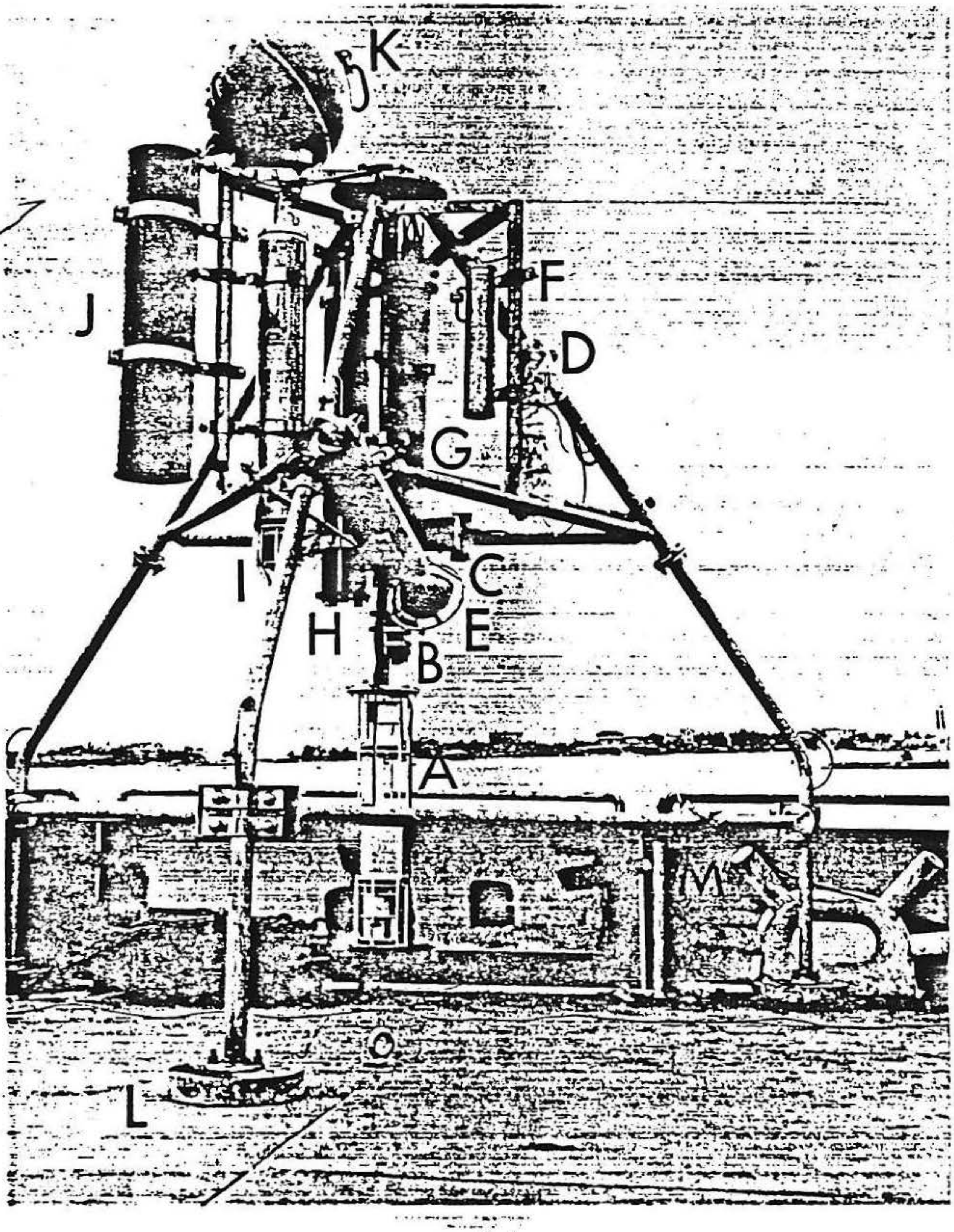


Figure 3. U.S. Geological Survey Tripod System: (A) current sensor (this photograph is of a modified system with two savonius rotors); (B) pressure sensor; (C) transmissometer; (D) camera (wrapped in protective plastic bag to enclose anti-fouling ring); (E) strobe light; (F) camera battery pack; (G) Sea Data electronics; (H) battery pressure housing; (I) acoustic release transponder; (J) rope cannister; (K) recovery float; and (L) lead anchor feet.

method does not require as much flotation as the instruments in Figures 1 and 2 since the flotation has to bring the line, not the entire instrument to the surface. However, a strong current has prevented recovery of these instruments when flotation is minimized. A similar frame was used extensively in Long Island Sound, in part to monitor turbidity with optical sensors around dredged sediment disposal sites. The particular frame used is matched to the sensor type and application in order to obtain the best results.

Accoustic command sytem:

In a simple system as shown in Figures 1 and 3, the acoustic release separates the instrument and anchor on command and acts as an acoustic transponder for positioning the instrument and for navigation. In a more complicated system, the acoustic release or additional acoustic system (see Figure 2) sends signals to the surface ship or buoy. These messages warn of boundary violation, or transmit digital data to the ship or buoy on request. The acoustic release can receive and decode several commands allowing a ship or the tug and barge to command the monitoring equipment. This acoustic release is more complicated than typically used in the oceanographic community. In its most complicated form it:

1. Receives acoustic signals and decode them to
    a. command the system to enter a rapid sampling mode during a discharge event
    b. command digital data transmission
    c. shut down sampling until commanded again

    d. separate the anchor and instrument package

2. Transmits acoustic signals to
    a. acknowledge receipt of each acoustic command
    b. transmit digital data
    c. alert of any boundary violation
    d. act as an acoustic transponder as part of an acoustic navigation network for shipboard surveys

This acoustic release/transmission system is estimated to cost at least $12,000 each, and requires a shipboard command and receiving unit with a similar price. A simple acoustic release with only a release command, and perhaps an alert output costs as little as $3,000 for short duration, less secure operations.

Intelligent data system:

Processing and recording electronics. The various sensors require recording systems tailored to their abilities or capable of interfacing and processing a wide variety of inputs. With current microprocessor based, solid state recording systems, a whole new approach to data recording and processing is available. Software control of the system allows it to be easily adapted to a particular use. Internal clocks provide real time control accurate to seconds a month. Analog voltages are digitized and the signals processed before recording, so they can be converted to standard geophysical or engineering units. Therefore, the data is in a recognizable and easily understood form. The needed data storage space is also reduced. The hardware is simplified by the use of the microprocessor. Presently available hardware systems start at $800 for a simple environmental digitizer/recorder and extend up to $5,000 for a more complicated system. The real cost of this approach is in software development, which might require up to $50,000 to develop a complicated software package. However, the cost of reproducing this software is now tens of dollars. Therefore, after development costs are paid, new data logger/processing systems can be reproduced at less cost using microprocessor based electronics systems.

The advances in solid state memory make this the primary form for recording the data internally in the instrument. There are no moving parts as in a cassette tape recorder, and the data is more easily retrieved. Random Access Memory (RAM), now available in high density integrated circuits, is low in cost, low on energy use, easily available and is most often used in computers and remote instrumentation. It has the disadvantage, that if power is lost, the data is lost. Therefore, an extra battery on the memory board is necessary for backup power.

Another option would be to use UV Erasable Programmable Read Only Memory (EPROM) instead of RAM. These chips hold larger amounts of data, are cheaper and do not use any power to retain their data. This memory has the advantage of not loosing the data if power is lost, but it has to be physically removed from the instrument and placed under a UV light to erase the data. The power to program EPROMs (record data) is about equal to that expended using RAM. The newer electronically erasable EEPROMS offer the possibility of erasing the data in the pressure case after it has been retrieved. These devices are new to the market and do not possess a reliability history in oceanographic applications. The cost of memory is directly proportional to the amount required and is about $1,000 per megabyte of capacity. Therefore, memory for a simple system could cost from $500 to $2,000, for a complex system, depending on the sampling plan and requirements.

With solid state memories, the data is easily transferred directly to a personal computer (PC) for analyses. In the field it is possible to non-destructively dump the data to a portable terminal to assess what is happening, then later transfer the data to a PC or mainframe computer for further processing and analysis. A two-way acoustic link enables transfer of data stored in memory, thus the data actually stored in the in situ instrumentation is accessed while the instrument is on the sea floor. Retrieval of past data of concern is made without recovering the equipment and terminating site monitoring.

Acoustic sensing devices have the ability to create large amounts of data. If it is desirable to sample rapidly and store information for a long time, there are other high capacity storage devices that have just come on the market. Low power streaming tape recorders have the capacity to record 60 MegaBytes of data on a cartridge tape, using the power in a pack of standard flashlight batteries. The cost of this recorder is $4,000 to $5,000. For this same amount, an optical disk drive is available. This device is not so low powered, but has the capacity to write a Gigabyte (1,000,000,000 x 8 bits) of data on a write only disk. Either of these two systems could hold more data than one would ordinarily like to have to process for routine monitoring purposes. But it is often important to record densely spaced samples for a specific survey and general study purposes. With a modular approach, memory or recorders are easily added or removed from an instrument with only minor software modifications.

Knowledge based systems approach. A microprocessor based instrument has the ability to do more than just record data. With the power of the microcomputer, the data can be conditionally sampled, compressed and further processed for diagnostic and telemetry purposes (Irish, et. al., 1981, Irish, et. al., 1984). Using advanced software, the intelligent instrument system can vary the sample rate to fit the observed signals. This is exactly what the weatherman does when he observes a storm approaching. The instrument routinely samples the "background" under normal conditions, then if the signal exceeds what the instrument expects, based on what it has observed, the instrument increases the sample interval, perhaps, from twice daily to once per minute. Thus during a resuspension event, or a discharge of dredged sediment, the instrument automatically switches into a rapid sampling mode, and when the event ends and the signal returns to normal, the instrument shifts back to monitor mode. Conditional sampling does not save power as the instrument and sensor have to sample at the high rate to see what is happening. It does save on data storage space by utilizing it optimally. The system normally compresses the data so that uninteresting data is stored in a compressed form, thus saving on storage space. When an event is identified, additional high frequency data is recorded only when it is interesting.

With a telemetry link, the intelligent system can also compress the data so that it sends only a summary of what is happening. This allows the system to be routinely checked to see that it is working properly. The instruments have internal diagnostics which review battery power, storage space, and determine if the sensors are giving reasonable signals. Thus the system could be left in place indefinitely until it began to lose power. An acoustic link would not be capable of sending all the data that the instrument is capable of collecting, so that it would be advantageous for the microcomputer to have software designed to compress the data for telemetry purposes. If internal storage space is limited, the system compresses the data in a different manner for the solid state memory for monitoring purposes. Thus, software allows the system to use the power of the computer to adapt the instrument to the environment, the storage capacity and telemetry link.

Power considerations:

The power requirement of the instrument depends on the complexity of the system, what sensors are used and how much in situ processing is desired. Surface buoy solar panels have the capability for powering the system indefinitely. This is a proven technology that worked well on buoys UNH deployed for one year in the Gulf of Maine (Wood and Irish, 1987, Irish, et al, 1987). The bottom mounted microprocessor can cycle power to the sensors and itself to save energy. A simple system is easily powered by standard flashlight batteries for months. The main power consumption is in the sensors themselves and, of course, a more complicated system requires more batteries. Ten kilowatt hours of lithium battery power is easily packed in a 6" diameter, 4' long pressure case providing power to a sophisticated system with acoustic sensor for several months. The instrument in figure 2 has two such battery packs. However, a 10 kwh battery pack costs about $4,500.

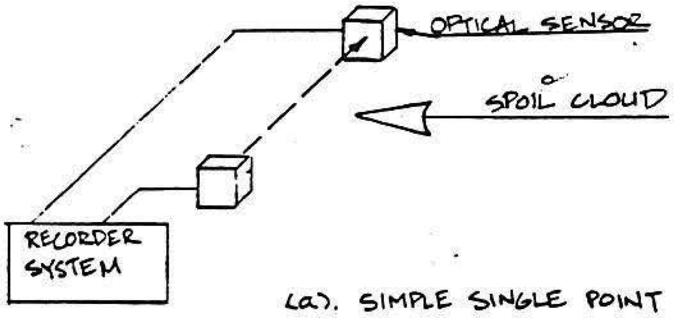
Sensors and sensor options:

Sensors are the important interface between the intelligent data system and the environment, and as such, are the most critical part of the proposed monitoring instrumentation. Acoustical and optical sensors are routinely used to monitor water column events. Both kinds of sensors are used in both transmission and scattering configurations depending on the application. The transmission measurement technique requires a signal to traverse the medium between two sensing elements, which could be on the same instrument or on separate platforms. The received signal is a function of the transmitted signal strength, the integrated cross section of the particles in the path, and the receiver aperture. Changes in the received signal are monitored, acceptable levels are set and used to define a boundary violation. The scattering measurement technique generally uses a single sensor which acts as a transmitter and receiver. The backscattered energy is a function of the signal strength, the density of scatterers, and the receiver aperture. The received signal is monitored and used to determine if the sediment cloud enters the sensor beam. The scattered return signal in an acoustic sensor can be range gated or divided up into sections which allows the instrument to determine the distribution of scatterers as a function of distance along the beam.

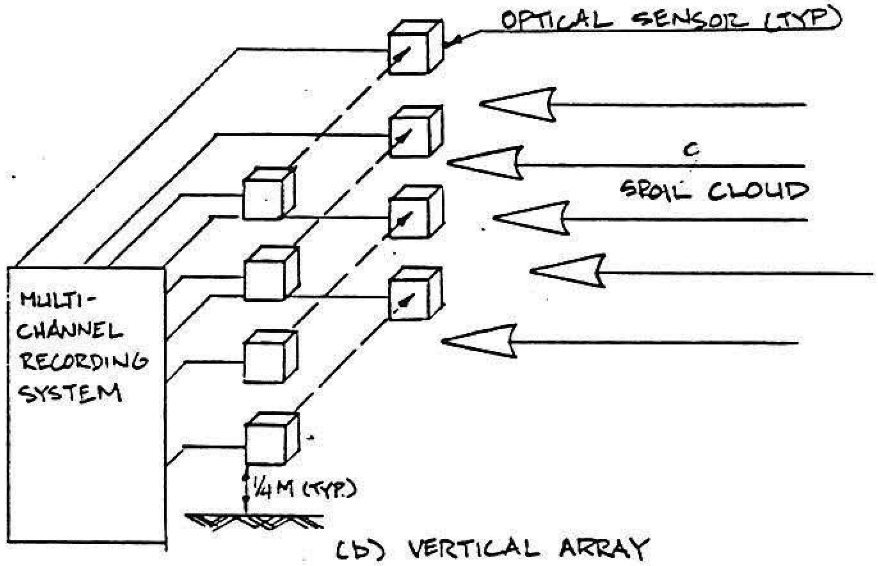
Optical techniques:

Single Point Optical Measurements - The simplest system is a transmissometer at a fixed distance above the bottom which provides a single point measurement (Figure 4A). The sensor could be any of the various transmissometers on the market today. They range in cost from $2,000 to $8,000, and output a signal proportional to the percentage of light or sound transmitted. Commercial units are produced by ENDECO of Marion, MA, or Sea Tech of Corvallis, OR. Reflection or backscattered measurements are also made for similar cost, and claim to have a larger range of measurement. Downing & Associates of Redmond, WA manufactures a line of optical backscatterance sensors.

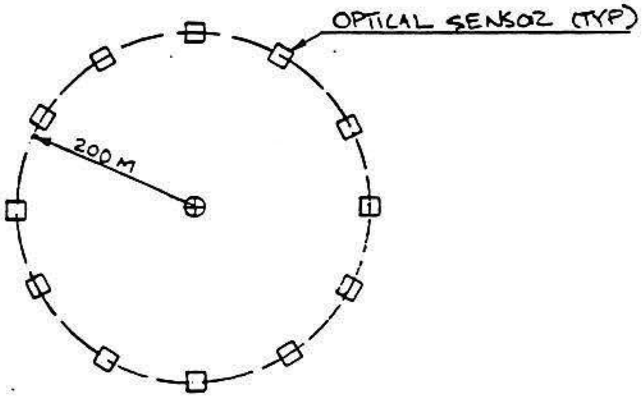
However, if the purpose is to monitor the presence of an extended cloud of suspended sediment, then it would be simpler to build an uncalibrated instrument which uses an LED-Pholotransistor pair as an optical switch. From laboratory and field studies with more sophisticated instrumentation, a threshold for a given pathlength is selected which is appropriate to recognize the sediment cloud. This sensor does not require the sensitivity, linearity and size of the normal



(a). SIMPLE SINGLE POINT



(b) VERTICAL ARRAY



(c) DEPLOYMENT

Figure 4. (A) A simple optical switch measures when the suspended sediment is between the sensors. (B) A vertical array of four sensors can also give information on the height of the sediment cloud. (C) The deployment of 12 sensor systems, as in A and B above, to monitor a disposal site.

transmissometer, and is less expensive to make. A simple optical "switch" and solid state recorder assembled from available parts, possibly using fiber optics, is readily installed in a pressure case for a little over $1,000 in parts. The recorder stores the times when the switch indicates that high sediment concentrations are observed, and the times when the concentrations at the sensor return to normal levels. Some hysteresis is be built into the system to accommodate turbulent variations in sediment concentration at the threshold which might cause multiple triggers in a single event.

Multiple point optical measurements - A vertical array of these simple optical sensors is easily constructed, e.g. four sensors at 1/4 m increments above the bottom (Figure 4B). Information on the vertical extent of the sediment cloud is then obtained. The data logger records the times of the observed events at each level. A single 256 kByte memory board on a system deployed for 6 months allows recording of the times of 100 events at each level per day to a 1 second resolution.

Such instruments are relatively inexpensive, and their design, efficiency and reliability could be optimized if many are made. Since a measurement is made only at each instrument, if the circumference of the disposal site is large, many instruments are required to densely cover the perimeter. Figure 4C shows a suggested deployment with 12 instruments surrounding a disposal site. Such an array requires acoustic releases with at least 12 different release/command codes in order to recover the instruments one at a time in a controlled manner.

Acoustic techniques:

Vertical profiling. The vertical distribution of sediment concentration and the exact height of the slurry of dredged sediments are measured by acoustical techniques (Stanton, et. al., 1987, Orr and Baxter, 1983, Proni and Hansen, 1981). A single element, downward looking, high frequency acoustic sensor measures the backscattered energy as a function of range, and hence the vertical suspended sediment distribution as well as the distance to the bottom. The frame shown in Figure 3 holds such a sensor and samples the water column as shown in Figure 5. The sensor is more sophisticated than the simple optical switch, and costs in the $3,000 to $4,000 range, the same as the calibrated transmissometer. Datasonics, of Cataumet, MA, makes this type of instrument called a sonar altimeter. The signal processing is dependent on the desired output. A simple time series of the height of the maximum backscattered signal is recorded, or more sophisticated processing yields complete vertical profiles of backscattered energy dependent on the suspended sediment distribution. The latter method requires more data storage capacity and processing time thus it increases the costs for added memory or results in shorter deployments. Hourly samples of 1 cm bins for 3 meters vertical distance with time, pressure, temperature and current velocity require about 250 kBytes per month. A system with 1 MByte of EPROM memory lasts 4 months.

Horizontal Acoustic Measurements. Acoustic systems can detect suspended sediment at some distance from the instrument; acoustic techniques are capable of monitoring the sediment concentration

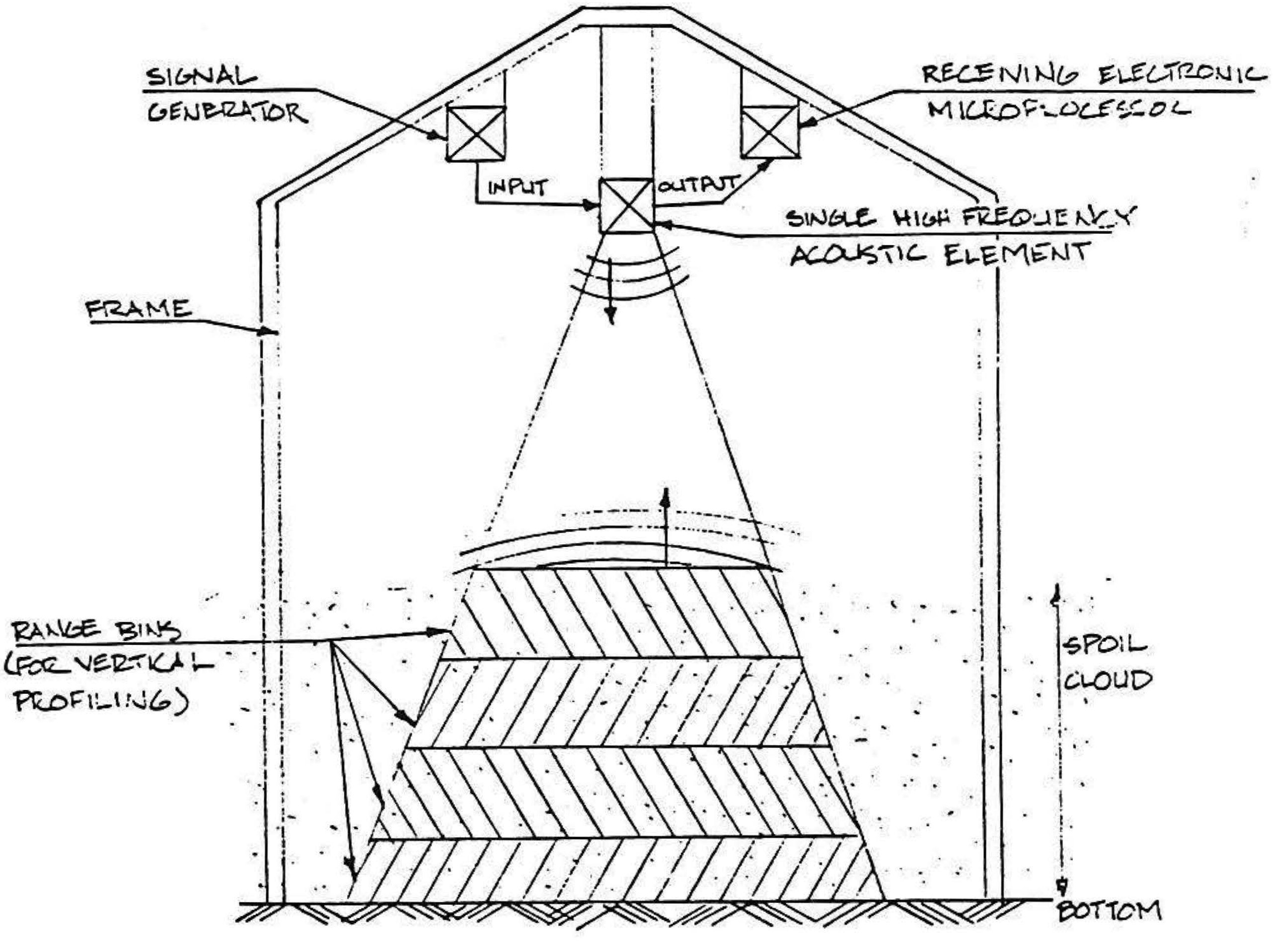


Figure 5. Vertical profiles of sediment distribution are measured by a single downward looking transducer mounted on an open type of instrument frame such as shown in figure 3.

as a function of horizontal distance. This is more sophisticated and uses unproven technology, but is the most promising for spatial monitoring of a disposal site.

The central instrument platform has acoustic sensors mounted on top which monitor the full 360 degrees around the instrument. The acoustic sensors operate between 200-300 kHz. Either six or eight arrays with a horizontal beam pattern designed to cover the full circle, are deployed on a single frame (see Figure 6A). Each array has a beam of narrow vertical extent (3 degrees) and a broad horizontal extent (50 degrees). This is effectively deploying a side scan array in a vertical orientation (see figure 6B). A signal is transmitted from each array, and the received signal is range gated to achieve 10 m horizontal resolution. The signal integrated over the 3^{o} x 50^{o} solid angle in a specific range bin. The geometry of the system is shown in figure 7, illustrating why the narrow vertical beam is essential. The water column boundary effects (surface and bottom) on the signal contamination and range capabilities are presently ill defined and will require some research.

At 300 kHz, the sampling range of this proposed instrument is estimated to start at 5 m from the acoustic array, and extend to at least 100 m and possibly as far as 200 m. Near field effects prohibit measurements closer than 5 m. An increase in acoustic frequency enhances scattering from suspended material, but decreases the range due to increased attenuation. Time varying gain incorporated in the analog receiver amplifiers and signal processing compensates for geometrical spreading loss.

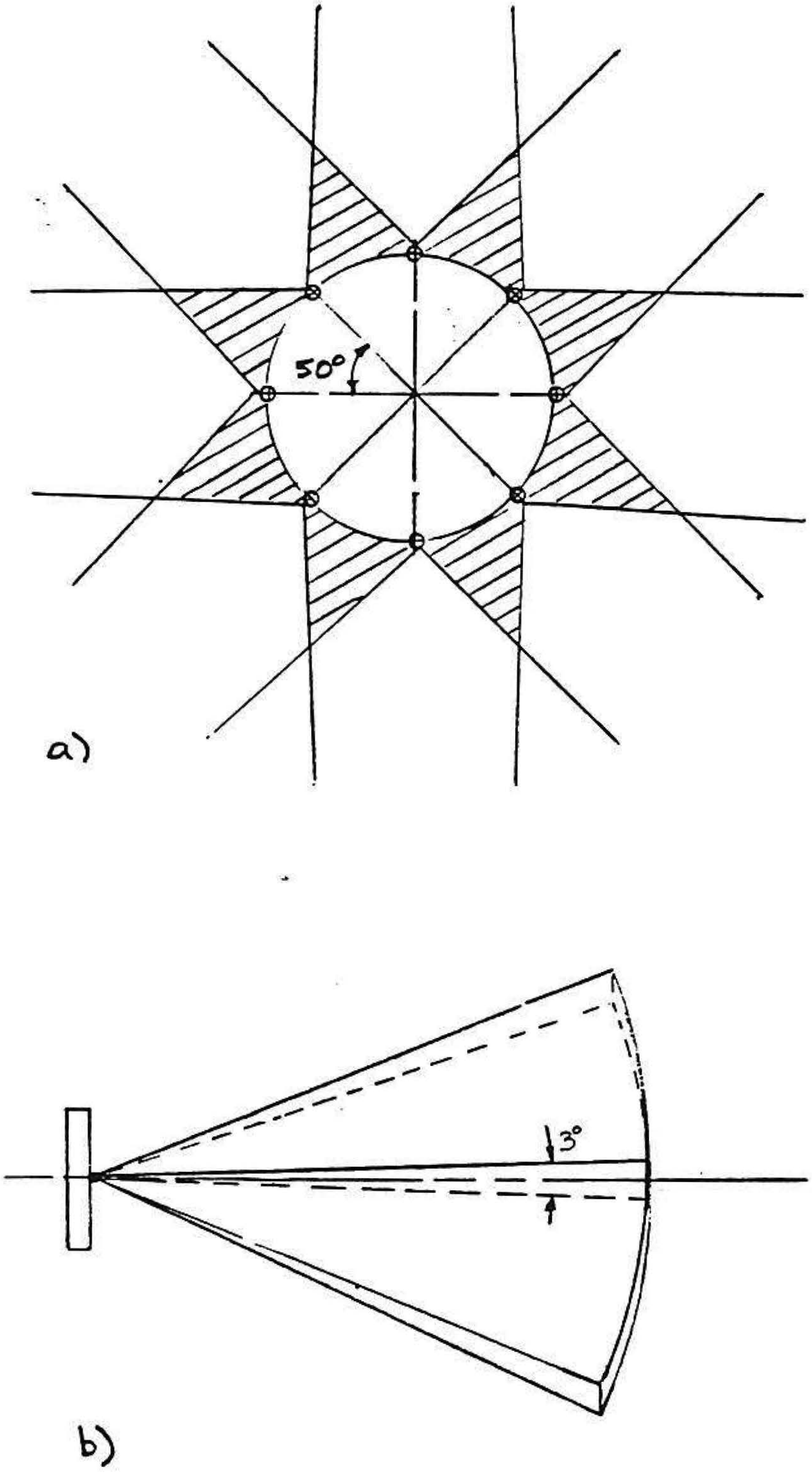


Figure 6. (A) Plan view of the multi-element acoustic array showing how the beams cover 360° around the instrument. (B) The beam pattern of one of the acoustic transducers in the array has a narrow vertical and broad horizontal beam pattern.

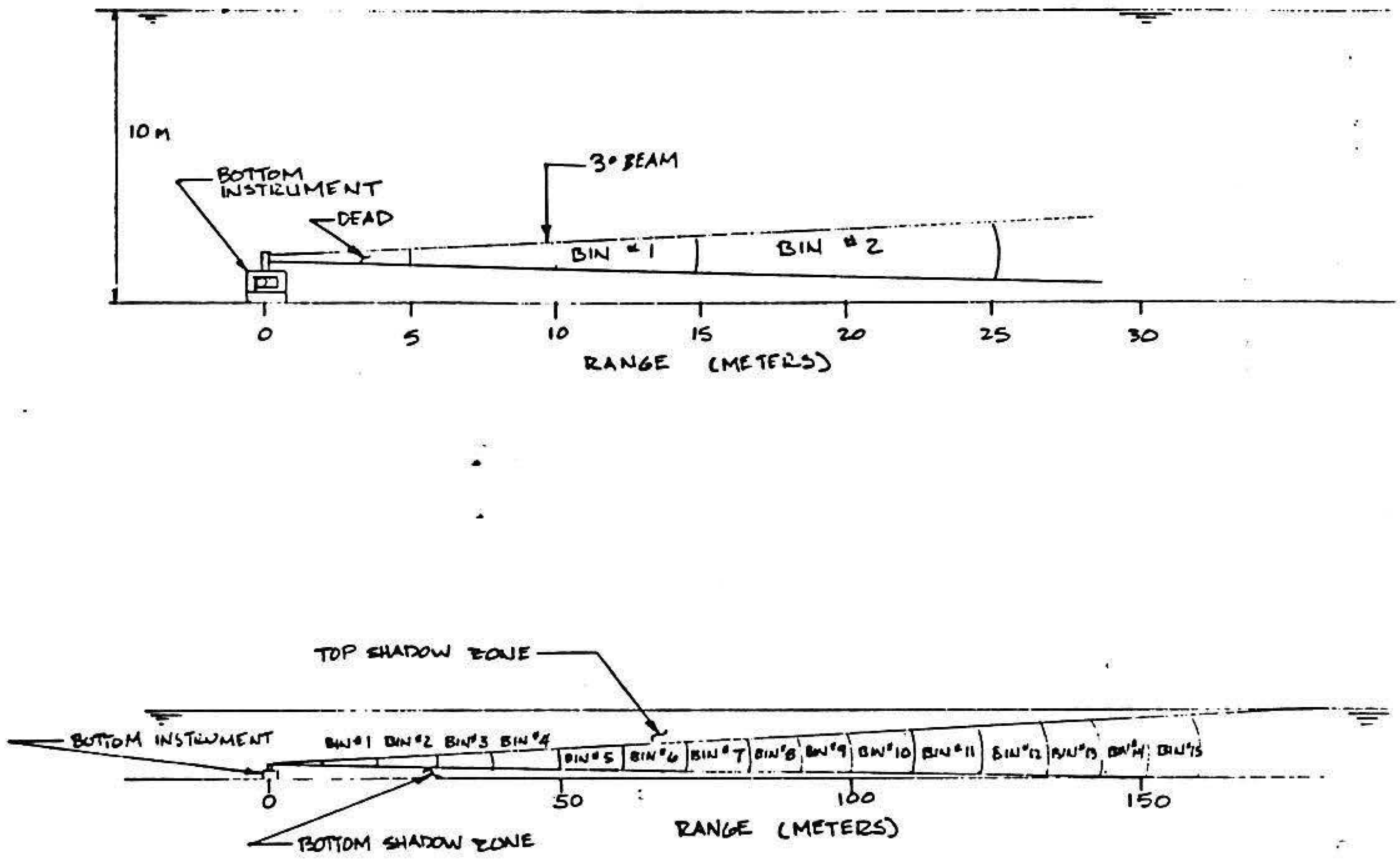


Figure 7. The water column as sampled by the horizontally looking acoustic instrument. A detailed view of the instrument is shown at top and an overview at the bottom.

Signals are digitized and stored on board in solid state memory. Depending on the complexity of the sampling program, all the data is stored in raw form, or processed and reduced to only identify the time and bin of high suspended sediment concentration. A school of fish might look surprisingly like a sediment cloud, and could impose a limitation on interpreting the data. Knowledge-based processing, however, should filter out these effects.

With an intelligent data system, data is continually acquired, and a background of data during normal conditions achieved. The instrumentation is programmed to conditionally sample, that is recognize any deviation from normal, and store the details of that event. Therefore, if an unusually large storm resuspends bottom sediments a record of this is obtained. The system also compresses the data and transmits the time, and bin of any high suspended sediment concentrations via acoustics and radio to shore or shipboard for further study or action.

Site marker buoy and telemetry:

The final link in any of the concepts is the ability to communicate between a shorebased station and the bottom mounted instrument package. The mechanical configuration and block diagram of a buoy telemetry system are summarized in Figures 8 and 9. The surface buoy marking the dump site has instrumentation required for two-way transmission of data by an acoustic link from the bottom mounted monitoring packages and relaying this data to a shore station via radio transmissions. Several bottom monitors could communicate through a single

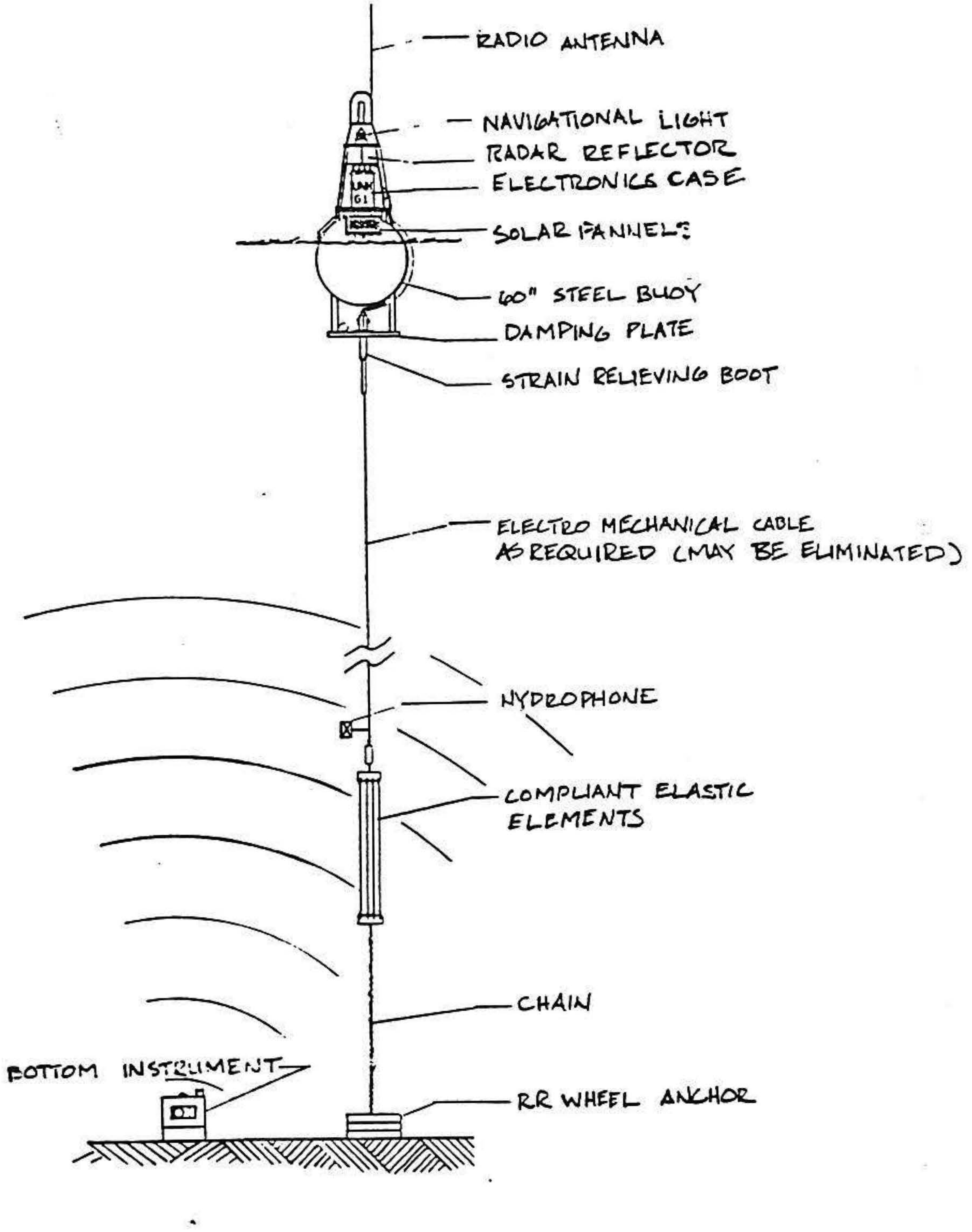


Figure 8. The surface buoy configuration for a spoils marker buoy which would double as a data telemetry relay station.

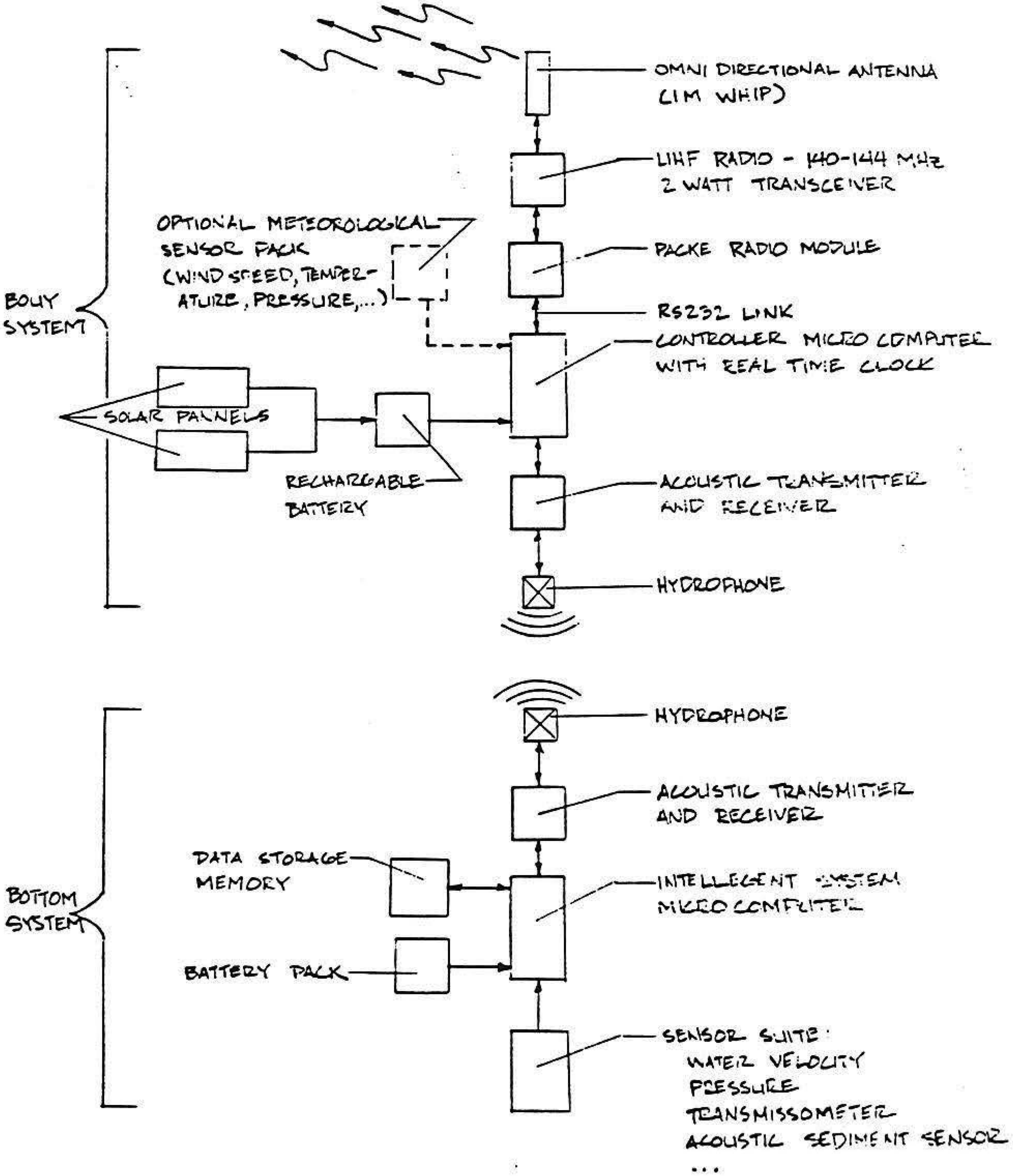


Figure 9. A block diagram of the bottom instrument and buoy telemetry link.

surface buoy. The system involves a two-way link via radio to the buoy and acoustically to the bottom instrumentation. In addition to acting as a backup of the internal recording system, it allows someone on shore to activate the in situ monitoring arrays by acoustically commanding them to enter their rapid sampling mode. Since the link can send data to anyone within radio range, an independent agency can easily monitor the dump site, and receive information on a specific discharges, background information during a storm, as well as any alert of boundary violations.

The two-way acoustic link is still in the development stage. Several systems have been built and the feasibility of transmitting data has been proven. No commercially available units are ready, but developments at WHOI, Sea Data of Newton, MA and Datasonics, of Cataumet, MA show potential for several options within the next year. A backup plan would be to use a custom built unit, which will cost considerably more, but work just as well.

A simple two-way voice grade VHF radio link using packet radio protocol, connects a computer storing data in the buoy with a computer on shore acting as a base station. A commercial version of a two-way packet radio link with base station and computer is available from ENDECO of Marion, MA for about $10,000. The buoy based microcomputer is interfaced to an acoustic link which communicates with the bottom mounted instrumentation, and receives digital data acoustically transmitted from the bottom instrumentation. The two-way acoustic link costs about $8,000 at each end as a separate piece of equipment, or can be incorporated into an acoustic release at a reduced cost. Such systems are not normally used commercially and need to be custom build or adapted to this application; costs would decrease if they became commercially available. Solar panels power the buoy system and lengthen the time between buoy servicing. The use of BuoyTech of Concord, NH. compliant members in the mooring reduce the hardware acoustic noise, and makes the buoy ride more smoothly which will in turn improve the acoustic and radio links. The buoy and monitoring instrumentation can also be accessed by radio from shipboard.

Conclusions and Recommendations

The in situ, real time monitoring systems described in this report are all technically feasible and provide a broad range of flexible applications adaptable to specific monitoring needs. A functional monitoring package consists of a frame, a power supply, sensors, a microprocessor controlled data logger, a two-way acoustic data link, an acoustic release and, perhaps, a buoyed radio link. The single point system using an optical sensor is simple, workable and easy to develop. Measurements a a single point may be adequate if the location is judicially chosen. However, a large number of instruments may be required to monitor the entire perimeter. This may be prohibitively expensive as the logistics of deployment and system maintenance become overwhelming. In addition, this approach does not take advantage of the latest technology in remote acoustic sensing, and, therefore, may not be the best solution in the long term.

The acoustic survey approach, with an intelligent data system, allows more complete spatial pictures to be obtained, yet remains flexible for future developments. The smart acoustic instrumentation, however, is not now commercially available, the parts that are available are not packaged or interfaced appropriately, nor have they been evaluated for their ability to monitor a dredged sediment discharge in the way we have described.

Although we do not recommend the single-point approach as a long-term solution to monitoring the fate of dredged sediment during the discharge operation, it may be adequate in some situations and we recommend that it be used in the first stage of an incremental development program aimed at producing functional but successively more sophisticated monitors. This development program allows development monitors to be deployed in active disposal operations while sensors and data links are undergoing further evolution.

The focus of the first stage is to produce a self contained monitoring system using an optical transmissometer that logs turbidity data: the elements of this stage of development include:

1. An instrument platform
2. An acoustic release and deck support unit
3. A commercially available transmissometer
4. An intelligent data logging system with microprocessor, 256 kbits of storage memory, a digitizer, a clock, pressure case for these electronics and a battery pack.
5. The development and testing of an optical switch

6. Field tests

This first stage is anticipated to take 12 months and cost about $160,000.

The focus of the second stage of development is the addition of an acoustic and radio telemetry capability to the bottom instrument system developed in stage one. The elements of this state of development include:

1. A two-way acoustic telemetry link
2. A surface buoy with acoustic and radio capability
3. A two-way packet radio link with base station computer
4. Full scale field testing of instrument with optical switch
5. Initial development of horizontal acoustic sensor

This second stage is anticipate to take another 12 months and cost about $160,000.

Subsequent stages would involve the development of the horizontal acoustic sensor, deployments, full field testing, evaluation and intercomparisons with other techniques and sensor systems. During these stages an operational system for the effective use of such a monitoring device would be determined. A bottom platform with smart data logger will be constructed and tested by the end of stage two. This instrument would then be a platform which could be used for further development and testing of additional sensors and techniques for monitoring discharge operations.

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