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PRELIMINARY SUMMARY OF DEPLOYMENT WORKSHOP*

LaJolla, CA., Dec. 1-5, 1980.

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ABSTRACT

The 1980 Deployment Workshop was attended by 20 physicists and engineers. It considered the problems of deploying several hypothetical DUMAND arrays, ranging from MICRO to MIDI. Three different deployment techniques were discussed, and two found plausible. Preliminary cost estimates are given. No insuperable difficulties were foreseen; but the deployment of massive or large detectors complicates deployment and is expensive, requiring more ship time. The group also considered the possible shallow deployment of a group of auxiliary twin detectors, to improve the usefulness of DUMAND as a cosmic-ray shower detector. It was not able to show that such deployment was impractical (as had been widely predicted), but good cost estimates are not yet available. Detailed results will appear in the published proceedings of the workshop.

INTRODUCTION

The 1980 DUMAND Deployment Workshop at LaJolla was attended by 20 physicists and engineers (see Appendix 1 for list.) It was the first workshop on deployment since the 1978 Summer Workshop (1), and its purpose was to reconsider deployment ideas and procedures in view of the extensive changes that had occurred in the concept of DUMAND arrays; to consider new concepts of deployment, and to estimate costs.

Before the workshop some new deployment concepts had been advanced. R. Talkington (NOSE, San Diego) had described a "Master Buoy" concept at the 1980 DUMAND Summer Workshop in Honolulu (2), and G. Wilkins (NOSE, Kaneohe) had proposed a guided-drop concept (3). In addition, further thinking on the drill-ship concept proposed in 1978 had also been fruitful.

On the array side, the original 1978 DUMAND Standard Array had long since been abandoned as impractically large and expensive, and much thought had gone into the design of smaller arrays, and into the study of their usefulness. In consequence of all this, the Workshop Director (A. Roberts) prepared a memorandum (4) to the workshop that outlined the arrays to be considered by the workshop, and described the deployment procedures proposed to that time. The participants were consequently well briefed before arrival; and the first morning's recapitulation of the array descriptions and deployment procedures

*Proceedings of the Workshop, containing complete reports from each working group, will be published by the Hawaii DUMAND Center.

was adequate to give the several workshop groups their instructions.

Four working groups were organized (see Appendix 2): one each to work on drill-ship deployment, the master-buoy concept, and the guided drop. The fourth group, a smaller one, was set up in response to requests to study a problem that comes up recurrently because of pressure from cosmic-ray physicists. The value of the DINDA deep array for studying high-energy cosmic-ray events would be greatly enhanced by supplementing it with another detector system, at or near the surface. Since great scepticism about the feasibility of such an installation had been expressed by many oceanographers and ocean engineers, it was hoped that this group might come up with a recommendation that would settle the question of feasibility once and for all.

The four working groups will be described in the following sections. The first group, the most important, is the INITIAL STATEMENT OF PROBLEM.

As first formulated, the arrays to be considered consisted of two versions of the dense array, with the same number of strings and sensors, but differing only in the spacing. They were called, respectively, the MINI and the MIDI. The arrays were also referred to as dense or sparse, and the spacings as narrow or wide, the narrow spacing (15m) requiring a lower sensitivity sensor ($S = 1$ stenger) and the wide spacing a high-sensitivity sensor ($S = 6$). (A sensitivity of S stengers means an average yield of S photoelectrons from the photocathode when illuminated by 100 photons/m².)

The second group, the DRILL-SHIP DEPLOYMENT GROUP, will be concerned with the design of the ship and its equipment, the development of methods for drilling through the ocean bottom, and the design of the array to be deployed. The third group, the SURFACE SYSTEM GROUP, will be concerned with the development of the array to be deployed at the surface, and the fourth group, the GUIDED DROPOFF GROUP, will be concerned with the development of the system for dropping the array into the ocean.

All four groups will have as part of their task the evaluation of the scientific objectives of the array, the design of the array, the development of the array, and the evaluation of the array's performance. The fourth group will also be responsible for the development of the array's control system, and the third group will be responsible for the development of the array's power supply system.

The first group will consist of a number of individuals who have experience in the design and construction of deep-sea arrays, and who have experience in the design and construction of deep-sea arrays. The second group will consist of a number of individuals who have experience in the design and construction of deep-sea arrays, and who have experience in the design and construction of deep-sea arrays. The third group will consist of a number of individuals who have experience in the design and construction of deep-sea arrays, and who have experience in the design and construction of deep-sea arrays. The fourth group will consist of a number of individuals who have experience in the design and construction of deep-sea arrays, and who have experience in the design and construction of deep-sea arrays.

The initial state report contains a detailed description of the performance of the array, and a report on the results of testing and calibration of the array.

and the additional benefit to **TABLE 17: DICTIONARY OF DEMAND ARRAYS**, in terms of the
number of entries, provided by the **TABLE FOR WORKSHOP STYLES**. In total, there will be
approximately 400 base applications of this methodology and some 3000 corresponding
ARRAY NAMES such as **MIDDLE-LIGHT**, **NECRO-N-NECRO-N**, etc. At the same time,
there will be approximately 100 **DIMINISHING DEMAND** arrays and some 1000 associated with the
base array **NECRO-N-NECRO-N**. The total number of arrays will be approximately 4000.
The **PROBLEMS** in base **NECRO-N-NECRO-N** will have a volume of 3.4x10⁶ and a size of
about 1000000 bytes and a **SP2210²** of 3.10³ K-5x10⁷ is the expected

aber was weiter soll selbstredend passen. Einzelheiten "Englisch" bzw. "Welt" sind
eigentlich so beschränkt, dass sie auf die entsprechenden geographischen und kulturellen
und sprachlichen Ausdrucksbedarfe des jeweiligen Kurses abgestimmt werden
müssen. Wenn man z.B. einen Kurs für Erwachsene mit dem Titel "Englisch für
Touristen" hat, dann kann man dies "Englisch für Touristen" nennen.

In November, just before the workshop, Talkington offered another still smaller array, which he thought of at first merely as an initial exercise in deployment (5), since it contained only 19 strings and 209 sensors. However, Monte Carlo calculations by Roberts indicated that the array was in fact useful for detecting muons, and so the array, taking Table 1, contains this "MICRO-DUMAND" array in addition to MINI and MIDI. MICRO-DUMAND can also exist in versions with narrow and wide spacing, MICRO-N and MICRO-W, so that there are a total of four arrays to be considered: two with narrow and two with wide spacing.

In addition, each of these arrays can be designed as cubical, rhomboidal or hexagonal, as illustrated in Figs. 1 - 3. Table 2 describes the differences among these versions for the MINI array. The differences between these versions is small but significant; the hexagonal array is superior in that the furthest distance an interior point can have from a sensor is about 10% smaller for a hexagonal array than a cubic array with the same volume and number of sensors. The hexagonal arrays offer no difficulty in deployment, and most deployment schemes considered only that configuration.

Table 2. MINI-DUMAND Configurations, with narrow

PROPERTY	CUBE	RHOMBUS	HEXAGON
No. of strings on a side	11	11	7
Spacing between strings, m.	15	16.12	16.12
Spacing along strings, m.	15	15	15
Total No. of Strings	121	121	127/3
Sensors per string	11	11	11
Total No. of sensors	1331	1331	1397
Length of bottom edge, m.	150	161.2	96.72
Array height, m.	150	150	150
Area of bottom, m^2	22500	22500	24304
Volume of Array, m^3	3.37×10^6	3.37×10^6	3.65×10^6
Typical Diagonal, m.	212	241	230
Avg No of sensors/track	12	12	11
Maximum Distance of an Interior Point from nearest sensor, m.	16.77	15.14	15.14

Definition of Sensors.

The "low" and "high" sensitivity sensors specified for narrow and wide spacings respectively are defined as having sensitivities of 1 and 6 stengers respectively (i.e. 1 or 6 is the average number of photoelectrons produced in a flux of 100 photons/ m^2 .) For the purposes of this workshop, the low sensitivity sensor is a 17" Benthos glass sphere with a 13" PMT inside, of essentially neutral buoyancy or slightly buoyant. Its weight in air is not over 50 kg.

The high-sensitivity version is given in two versions. One is the Sea Urchin, as developed in prototype form at the Hawaii DUNAND Center (6-8). The sensitivity is $S = 6$; but the weight in air is about 1400 kg., and the volume occupied, in the collapsed state in which it is deployed, is a cylinder 4m long and 1.6m diameter. Again, in water, the module is somewhat buoyant (ca. 30% up). Alternatively, the high-sensitivity module may be a cylindrical PMT, yet to be developed; its characteristics are conveniently summarized. It was supposed that it would be 0.6m in diameter and about 3m long.

These parameters are required to design the canisters that contain a string of sensors. They are summarized in Table 3.

Table 3: ~~Design and Deployment Parameters and Grid Effects~~
~~and the most likely choice for design to be employed in addition to the~~
~~existing~~ ~~canisters~~ ~~Properties for Deployment Study Purposes.~~

Description	Sensitivity	Dimensions, m.	Weight, Diam. Ht, in air, kg	Weight, in water, kg
Low sensitivity	1	1.5m sphere	50	-10
Benthos 17" sphere	1	1.5m sphere	50	-10

With 137 PMTs of diameter 0.6m, DUNAND has been designed with a grid height of 1.5m, resulting in a total height of 3.1m, as follows:

High-Sensitivity (with 137 "large" PMTs) resulting in a total height of 3.1m
 a) **Sea Urchin** (diam. 1.6m to 1.6m, ht 1.4m), total weight ≈ 60 kg.
 b) **Cylindrical PMT** (diam. 0.6m, ht 0.6m, 2.5m overall) and will be referred to as the **benthos** (with 137 PMTs of diameter 0.6m, total height 1.5m, total weight ≈ 50 kg.)

Design of Auxiliary Surface Array

One group was asked to consider a problem frequently raised by cosmic-ray physicists who want to increase the usefulness of DUNAND in the study of very high-energy meson-ray events in the atmosphere, which give rise to multiple muon events in DUNAND. Such events occur fairly frequently, and their nature could be much better understood if some additional information were available besides that furnished by DUNAND. Such data could be the density of the electron component at sea level, the density of the low-energy muon component at or near sea level, and the rate of development of the shower in the atmosphere. The corresponding equipment required to study these parameters, respectively, would be an electron-shower detector array, at or near sea level (10); a set of detectors to sample the muon density at or near sea level; or, finally, a fly-by-a-way or similar detector to survey the atmosphere just above DUNAND to obtain the cascade profile, to be located on land as close to DUNAND as possible. The latter has already been studied in some detail (9), and requires no added deployment. The special group considered only the other two possibilities.

(Following this discussion, the following was the final conclusion presented by all groups to the workshop; more detailed results will be presented in the proceedings of the workshop (to be published).)

1. The best and easiest way to expand the existing DUNAND system is to add a vertical array of detector modules (either a stack of modules or a single

INITIAL CONCLUSIONS OF THE DEPLOYMENT GROUP.

1. Drill Ship Deployment.

Starting from the concept developed in the 1970 workshop, of a deployment via an "oil" drill ship, the group settled, for definiteness, on the *Glenn L. Martin Challenger* as a prototype which might in fact become available for the short period required for deployment. The ship belongs to MMS and is normally scheduled for use by the JOIDES Deep-Sea Drilling Project, whose operation is centered at the Scripps Institution.

A drill ship has the advantage (see Fig. 4) that it can lower a drill string, consisting of long sections of 5" steel pipe securely fastened to each other, to depths of 3 miles or more, and drill into the bottom at that point. Techniques for controlling the drill string are well developed, and with the aid of acoustic transponders and conical guides over a drill hole, allow the ship to remove the drill from the hole, sail away, and return later to place the drill string back in the same hole. The bottom end of the drill string can be controlled by thrusters to position it exactly.

This capability can be used by DUMAND. The drill-ship group proposed a technique in which an entire string was packaged into a canister with a hole in the center, which they christened a "bagel" (see Figs. 5-6). Depending on the size of the bagel and the handling capacity of the ship and drill string, a number of bagels can be threaded on the same drill string (all bagels need to be displayed in New York east side delicatessens.) Thus attired (see Figs. 7-8), the drill string can be moved around over the ocean bottom (Fig. 9), carefully depositing one bagel at a time at suitable locations, using position information provided either by an explicit checkerboard marking system, or implicitly by acoustic transponders that define a coordinate system.

The size and weight of the bagels depends on the sensors used (Figs. 5-6). For the low-sensitivity sensors postulated for the multi-spaced arrays, it is thought feasible to load the entire 121 strings of the DUMAND array on a single drill string, so that there is only one deployment module. The deployment operation would then consist of the following stages:

1. Assemble all 121 bagels on a drill-string core, on land (Fig. 10).
2. Launch the array into the ocean, with buoys (or bumpers) at both ends, to keep it afloat, but some distance below the surface (Fig. 11, step 1).
3. Tow the array out to sea, where the drill ship is waiting at the designated site, with coordinate markers already installed on the bottom.
4. Tip up the drill string, and maneuver one end under the drill ship. Fasten the upper end to the drilling equipment on the drill ship (Fig. 11, steps 2 and 3).
5. Extend the drill string until the bagels are close to the bottom. A section of shore cable is fed down the drill string with the array (Fig. 11 step 4).

6.1 Deposit the bags; one by one, at the proper locations. After all bags are deposited, the array can be deployed. Deployment involves no mobilization. In this scheme, the entire array is pre-wired, so that no connections need be made on the sea floor; nor is there any necessity for a remotely operated vehicle to observe or to assist. At the time of the deployment operation, the control computer is still attached to the drill string, and the cable-laying operation must begin at once, or can be postponed by attaching the cable to a buoy to be picked up later. It might also be worth to have an unjoined cable, so that bags can be avoided until the operations are planned better. The above operation is feasible in a single deployment package, described only for the low-sensitivity sensors, which can be packed up into a small bagel. For the cylindrical high-sensitivity sensor, the bags are much larger and fewer of them can be handled at one time on a drill string. In this case three separate deployment operations would be required for MID1. For Sea Urchin, the bags will still bigger (see Figure 6); only 13 bags can be carried at once, and two separate deployment operations are required. Needless to say, this cuts costs way up. (This is an argument for the use of drill ships without large drilling capacity - see "Glossy Explorer" - for large arrays; the economics of such ships needs to be explored.) It also introduces an interconnection problem between the separately deployed sections; this is discussed further below.

Table 4 gives the cost of system integration and delivery of OEMIM not hydro-harpoons and their equivalent in terms of cost. As to the MICRO, it is just possible that the wider-spaced MICRO-H₂ array, with 19 strings, might be deployed in a single pass if Sea Urchin is used.

Costs of various options and related E&I costs, weights etc., plus cost factors under this deployment concept are given in Tables 4 and 5. All figures add to constants up to 1000 ft, 1000 m, and 2100 m depth of water.

Table 4: "Bogal" Canister Cost Estimates, in \$/canister	
Assembly	1.1
Deployment system (includes array, canisters, cables, etc.)	1.1
Item quantity required:	
Low Sensitivity	High Sensitivity
Cylindrical bags	103
Spherical bags	103
Sheath (100' 1/2" x 1/2" diameter) 100 ft	100 ft
Cable (1000 ft, 1000 m, 2100 m)	1000 ft, 1000 m, 2100 m
Internal Connections (13.3 ft, 100 ft, 1000 ft, 2100 ft)	13.3 ft, 100 ft, 1000 ft, 2100 ft
Assembly	1.1
Quality Control	0.55
Delivery	0.35
TOTAL	6.70
	14.75

2. The Master Buoy Concept.

As originally suggested by Talkington (5), this concept allows the deployment of a complete MICRO array (19 canisters) or the equivalent, from a less expensive ship than a drill ship. A drill string is not required, merely the capability of lowering a deployment module of the required size. The module need not be lowered from aboard ship; it can be towed out to sea under water, or on a platform capable of being submerged.

As developed at the workshop, the original master buoy design required modification at several points. Thus, for the narrow spacing, the glide bodies simply do not have enough flight path to reach their terminal glide angle or velocity. Fig. 12 shows a plan view of the 19 strings that make up a MICRO array. This array is deployed in three separate stages. The central canister, directly under the master buoy, is simply deposited on the ocean floor. The inner ring of six, too close to be deposited by glide bodies, is located by means of arms of the right length that bend down (as from an elbow), and deposit the canisters on the bottom. Fig. 13 shows the master buoy, with a concrete anchor on the bottom, six vertical truss-work arms, that carry one canister each, and above that two rows of six glide bodies each that make up the outer ring of six. The outer ring is deployed last. In addition to the cost of glide bodies there is an extra cost for the bending arms and their deployment.

This significant departure from the glide-body concept marks the introduction of a new deployment technique, which we might call the elbow or bending arm, that seems to warrant further study to see how well it might compete with the glide-body technique, even in the range where the latter is practical. For short distances the bending arm is superior; at long range, for a not too large a glide body, the latter may be preferable.

For larger arrays like MINI and MIDI, the glide-body concept requires that a series of adjacent hexagons like that described above for MICRO be laid down. Fig. 14 is a diagram of a MINI array as laid down by the Master Buoy procedure. The final array is seven hexagons, plus surrounding a central one, each with 19 strings, making 133 in all. The array no longer forms an uninterrupted lattice structure; the boundaries between hexagons appear like lattice defects. This has no effect on the performance of the array.

In this scheme of deployment, the Sea Urchin canisters are so large that the simple glide-body method for carrying them to the bottom no longer appears practical. The glide bodies become as large as a fighter plane, and need much more substantial structure. Their cost therefore rises to a value that makes the system impractical. This is demonstrated in Table 5B, which summarizes costs for the Master Buoy procedure. It is clear that MIDI is excessively expensive when deployed by this method; for that reason deployment appears preferable. In Table 5 deployment schemes for both schemes are given.

It is worth repeating that these cost estimates are very preliminary; in the very limited time available during the workshop, the groups did not even have sufficient time to consult each other on the costs to be included in their estimates.

Indeed, the results reported in Table 5B are based on the assumption that the cost of a single hexagonal cell is constant, so that costs increase linearly with size. However, you are probably aware that in reality there is a large qualitative difference between small hexagons and large ones. The cost of a small hexagon is likely to be dominated by the cost of the hardware used to support it, whereas the cost of a large hexagon will be dominated by the cost of the hardware used to support it.

TABLE 3. PRELIMINARY ESTIMATES OF DEPLOYMENT COSTS, IN \$M.

A. Drill Ship Deployment.

B. Master Buoy Deployment

Fabrication Cost	1.6	9.0	.24	.24	1.6
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Deployment and **Wearers** **1.0** at **6.0** were also **133** reporting **95** %
of those deployed reported 80% or less fatigue. No significant effect was found
between the total **Wearers** and **TOTAL** rate of **14.75** vs **15.3** and **16.68** for **102** which is not
surprising given the small number of wearers in each category. **102** were
in a mixed situation, 32 were in a single scenario, 20 were in a mixed
scenario and 48 were in a single scenario. No significant effect between the **Wearers** and **TOTAL**

3. Guided Drop, and the Interconnection Problem.

The guided drop was considered only briefly, and succeeded in a concerted attack on it by proponents of the other schemes. They found it vulnerable on two important counts:

1. In the other deployment scheme, the array is completely hard-wired before (or during) deployment, so that no connections need be made underwater. A cable emerges from the final array that connects directly to the cable to shore, the connection being made on the surface.

2. Similarly, in the other schemes, there is no need for an unattended remotely operated vehicle (ROV) to oversee operations or to carry out basic operations? What are the costs and benefits of both options?

3. Perhaps most important, the guided drop is a new and untested technique.

nology; nothing quite like it has been done. Extensive development may be necessary.

The guided drop system requires both an ROV and underwater connections. It is possible to defend such requirements as feasible; were they unavoidable, we could no doubt live with them. Since they are not, and introduce an additional degree of uncertainty, they appear undesirable. The uncertainty is compounded by the fact that no ROV suitable for operation at 15000 feet now exists. In the face of these objections, the guided-drop group, guided by the old political principle "If you can't lick 'em, join 'em," decided not to submit a formal deployment plan, and contented itself with making suggestions to the other groups. For example, they pointed out that in any scheme using multiple deployments, there is a problem in connecting the separately deployed sections together. If the interconnections are made on the surface, the interconnecting cables, each the array depth in length, i.e. about 4.5 km, would be connected to a central junction box. To make short interconnections on the bottom requires underwater connections and an ROV. In the former case, aside from the great length of such interconnections, their storage on the bottom presents difficulties. Thus the ability to make permanent and reliable connections at great depths would be of great benefit to DUMAND.

4. Deployment of an Auxiliary Shallow Sub-surface Array.

A shallow subsurface muon array as an adjunct to DUMAND has been discussed in some detail by Grieder et al. (10). The proposed detectors, about 100m^2 each, are assumed to be at a depth of about 50m, and their spacing determines the lowest energy shower that can be detected by the array. Since the module cost is a small fraction of the deployment cost, we assumed a 200m spacing between modules, thus assuring a high rate of detection and a low threshold energy.

For the purposes of this exercise, it was assumed that the sub-surface or surface array would consist of individual modules (Cerenkov detectors) about 10m in diameter and 1m thick, deployed to sample an area of 1 km^2 at a spacing of 200m. There were then two alternatives: an array on the surface or just below it (to detect electron showers), or an array at moderate depths - 30m to 50m, to avoid the surface weather - to detect low energy muons.

The deployment problem is then how to moor such an array to allow it to operate for five years or more. The first thought was to moor the array to a large floating buoy, expensive enough to be prohibitive.

The first conclusion was that the surface array could be immediately ruled out. Experience with moored buoys in Hawaiian waters indicates that their expected lifetime, under the combined attack of weather and Hawaiian fishermen, is short. Only the permanent mooring of barges, occupied by a crew to drive off vandals, would even allow consideration of a surface array, or even a subsurface array within easy range of the surface. Since even that prospect appeared expensive, further consideration was restricted to sub-surface arrays 30m or more deep.

This implies that we can only study the surface density of the low-energy muon component, with an energy threshold around 10 GeV. This is less advantageous than the soft component, but still valuable - especially since aphrodite

The deployment problem then boils down to that of anchoring and operating a sub-surface array, without using buoys that emerge through the surface. This is generally conceded to be a very difficult problem.

Two mooring procedures were considered: (i) open, a cable array triangular in shape (see Fig. 15) and about 1500m on a side with area 1 km², is moored by three vertical buoyed strings. This is called a "tense" mooring (Fig. 16). Alternatively, the mooring lines are "scoped"; i.e. carried off at an angle to widely spaced bottom anchors (Fig. 17).

A triangular array like that of Fig. 15 will not remain at a fixed depth in a horizontal plane when acted on by currents or storms. Consequently, if the circular detector modules (so shaped to minimize drag) are to remain at a fixed depth, there must be sensor elements to activate a depth-restoring mechanism, e.g. a winch. Thus, we envisage a system in which the sensor modules are tied to the nodes of the network of Fig. 15, and maintain themselves at the correct height above it by paying out or reeling in cable. Power is envisaged as coming up the long cables to the bottom which are supposed to be tied in to the DUMAND bottom array. This tie-in also takes care of data transmission to shore. Procedures for making the tie-in were not considered.

It may be that the depth-compensation system can be avoided, provided the total motion of the array is not excessive and the depth is monitored. The location of the sensors relative to the DUMAND bottom array must be monitored to a few meters.

The triangular array envisaged here is made up of cables capable of maintaining relative position only under tension. The question whether the array is ever subject to compressive forces demands an answer. It does not appear likely that such occasions will be frequent, but they cannot be excluded. No ready method for strengthening the network against compressive forces seems likely. The best suggestion is a framework around the outside that helps the array maintain its shape, not by resistance against compression (a rigid column would simply break), but by being flexible, maintaining the tautness of the edges in the same way that an archer's bow keeps the bowstring taut.

First estimates of costs are not too alarming (see Table 6); but they are probably under-estimated. They do not include, for example, anchors, triangulation equipment, or the tie-in to DUMAND. The installation cost for long moored cables, and the cost of the lines themselves, are not high. The most serious problem, and one difficult to quantify, seems to be the behavior of the sub-surface array under the stress of currents, storms, and other environmental hazards. Even the highly negative gut reaction of experienced marine engineers and oceanographers should not be ignored. It had been anticipated that certain considerations of the sub-surface array would immediately demonstrate its impracticality, which did indeed happen with the surface array. Since this has not happened, further study is indicated. It should be noted that somewhat similar arrays have been deployed for kelp-farming purposes, in shallower waters.

Dear Prof. Dr. G. - please be so kind to forward my writing to me. I am the responsible editor of the journal "Journal of Oceanography". I am looking forward to your reply.

and enough time by **Table 6. Surface Array - Cost Estimation in Millions of Dollars** to estimate the costs involved in the deployment of the array.

Surface Units:	36 @ \$20K	Subtotal	720
Surf. Cables (including section keeping)	1000 ft @ \$100/m	Subtotal	100
Array Cables:	36 @ \$5/m x 200m	Subtotal	56
Fittings:	1000 ft @ \$100/m	Subtotal	100
		Total	806
Landings:	1000 ft @ \$100/m	Subtotal	100
Scoped Lines:	3 @ \$30K	Subtotal	90
Subtotal	900	Total	120
Deployment cost:	1000 ft @ \$100/m	Subtotal	100
Deployment cost:	1000 ft @ \$100/m	Subtotal	100
Deployment cost:	1000 ft @ \$100/m	Subtotal	100
Total, alternative cost	300	Total	108

and for the **ASSEMBLY AS MORE** (one module per day) assembly cost (cost of site and mobilization of ships and boats at various times of year) is \$450 per day and **\$15,000/day x 6 mo.** or a total assembly cost of **\$450,000**.

ASSEMBLY ON SITE

Assume the modules are to be assembled on land, approximately 1000 ft below sea level. This will require **300 tons, 10-mo.** mobilization cost plus **300 tons, 10-mo.** assembly cost. Assume **2 tugs, 1 mo.** mobilization cost plus **100 tons, 10-mo.** assembly cost. **Subtotal** assembly cost is **300**. Assembly cost is **1000 ft @ \$100/m**. Assembly cost is **1000 ft @ \$100/m**. Assembly cost is **1000 ft @ \$100/m**. **GRAND TOTAL (Scoped)** cost is **\$1,766**. Total cost of wide-spaced array sensors and the array will be about \$1,766 million dollars. This is a conservative estimate.

COMMENTS

Pending the final detailed report from the several deployment study groups, I draw a few "tentative" conclusions that should not be materially altered by further study.

A. The problems of deployment depend critically on the size of the canisters, which in turn depends on the size of the sensors. The 100 sensitivity sensors, packaged in 17" diameter spheres, can be so packaged that 12 strings, containing 1331 sensors altogether - the complete MICRO-W array - can all be deployed in a single drill-string package. In contrast, Sea Urchin demands a large package that it may not even be possible to deploy the 19 strings of MICRO-W in a single package. In general wide array spending on multiple deployments.

B. A major problem for deploying wide-spaced arrays - the kind best suited to muon-neutrino detection - is the interconnecting cables between separate deployments, if they are required. There are three alternatives:

1. Make the interconnections on the sea floor, using an ROV and suitable underwater connectors.

2. Bring the cable from each deployment module to the surface, and connect them all to a common junction box at the surface. The cable to shore will start from this junction box. Then lower the junction box and all the interconnecting cables to the sea floor, without disturbing the array.

3. Bring the cable from the first module to the surface, and there connect it directly to the second one. Bring a cable from the second module to the surface and connect it to the third, and so on in a serial order. The interconnecting cables must be stowed on the bottom as each new module is deployed.

Each of these procedures has obvious drawbacks. The first is presently not technically feasible, to the absence of a suitable ROV. When such a vehicle becomes available, and a suitable reliable connector is designed, this procedure will become feasible. It should be noted that the reliability problem can be much alleviated by the use of redundant connections.

The second alternative has two drawbacks. First, it may be difficult to control the descent via which a long cable will arrange itself on the bottom when the bottom end is fixed and the top end is lowered from the surface. This problem probably has a solution. Secondly, the introduction of 4.5 km of cable introduces a fixed delay of 23 microseconds between each deployment module and the central junction box. Since we want to do timing to 5 nsec, it is important that this delay be known and, if possible, constant. Variations in ocean conditions may well vary the delay in the cable by more than 5 nsec. Such delays can be monitored and corrected for, but they introduce undesirable complications.

The third alternative may be regarded as a variant of the second; it carries the additional hazard that a cable break anywhere disables all modules beyond it, not merely one module.

Finally, it is unclear that deployment considerations may well be the deciding factor in the choice of high-sensitivity sensors. Small volume and mass will be most important. The arguments concerning the supposed fragility of Sea Urchin seem not too be irrelevant compared to the fact that Sea Urchin weighs 1400 kg/m³ and occupies a cylinder 1m in diameter and 4m long. It will be up to the physicists to design smaller, more compact, large photocathode area high-sensitivity sensors.

TENTATIVE CONCLUSIONS.

1. Deployment of the arrays considered is practical, by at least two methods not involving making underwater connections.

2. A choice of array sizes is available, and the smallest arrays considered can probably be deployed for less than \$1M. Such an array would do useful physics.

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10. Elbert, J., P. Grieder, M. Shapiro, G. Smith, E. Stocker, and V. Stenger, "Air Shower Detection Systems for DUMAND: Part 2. Low Energy Muon Array at Shallow Depth over DUMAND." DUMAND 80 (in press).
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Appendix I.

**Registers for DUMAND Deployment Workshop
LaJolla, CA., Dec. 1-5, 1980**

April, E.	NOSC, New London, Conn
Blood, H.	NOSC, San Diego
Bradner, H.	SIO/IGPP, LaJolla
Estabrook, A.	NOSC, San Diego
Gilbert, G.	NOSC, San Diego
Hultberg, S. D.	NOSC, San Diego
Jones, R. E.	NOSC, San Diego
Learned, J. G.	Hawaii DUMAND Center
Liu, F. C.	CEL, Port Hueneme, CA
MacTernan, F. C.	DSDP, SIO, LaJolla
Newton, F. L.	Global Marine Dev. Co., Newport Beach
Peterson, M. N. A.	DSDP, SIO, LaJolla
Peterson, V. Z.	Hawaii DUMAND Center
Reines, F.	UC, Irvine
Roberts, A.	Hawaii DUMAND Center
Schlosser, A.	NOSC, San Diego
Sonanshein, N.	Global Marine Dev. Co., Newport Beach
Talkington, H.	NOSC, San Diego
Walker, W. W.	Lockheed Ocean Systems, Sunnyvale, CA
Wilkins, G.	NOSC, Kaneohe, HI

APPENDIX 2**Deployment Workshop Groups.**

Participants in the workshop of the HSC and the DMSU will be assigned to one of the following groups:

Group 1. Surface Supported Concepts (Drill-Ship)

- A. Schlosser, NOSC
- N. Sonenschein, GMDO
- F. MacTernan, SIO
- E. April, NUSC

Group 2. Master Buoy

- R. Jones, NOSC
- A. Estabrook, NOSC
- F. Liu, CEL
- W. Walker, LMSC
- V. Peterson, HDC

Group 3. Guided Drop

- G. Wilkins, NOSC
- M. Peterson, SIO
- V. Peterson, HDC

Group 4. Subsurface Auxiliary Array

- A. Roberts, HDC
- S. Hultberg, NOSC
- G. Gilbert, NOSC
- J. Learned, HDC

Group 5. Overview

- A. Roberts, HDC
- H. Bradner, SIO
- J. Learned, HDC
- V. Peterson, HDC
- H. Talkington, NOSC
- G. Wilkins, NOSC

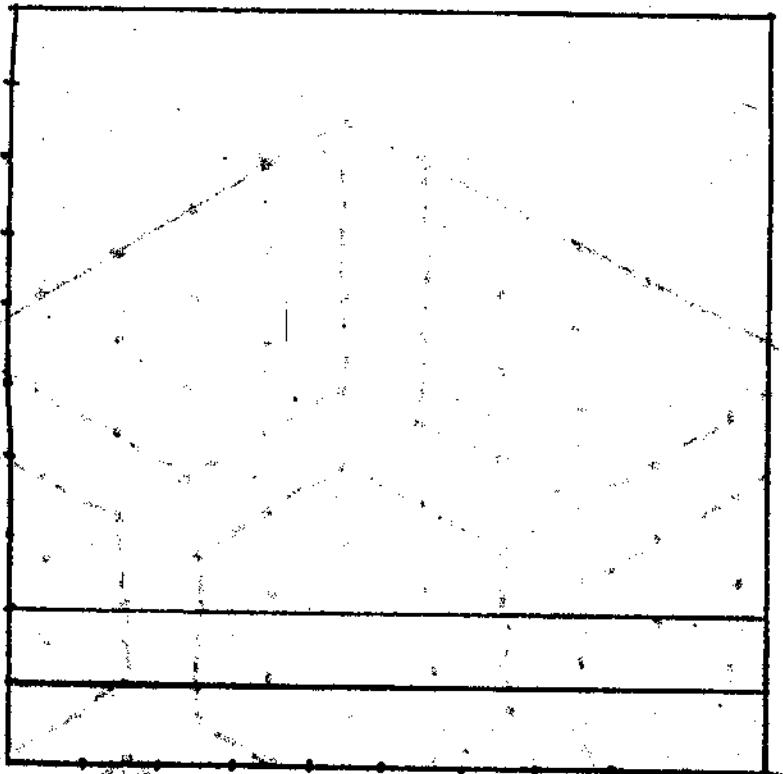
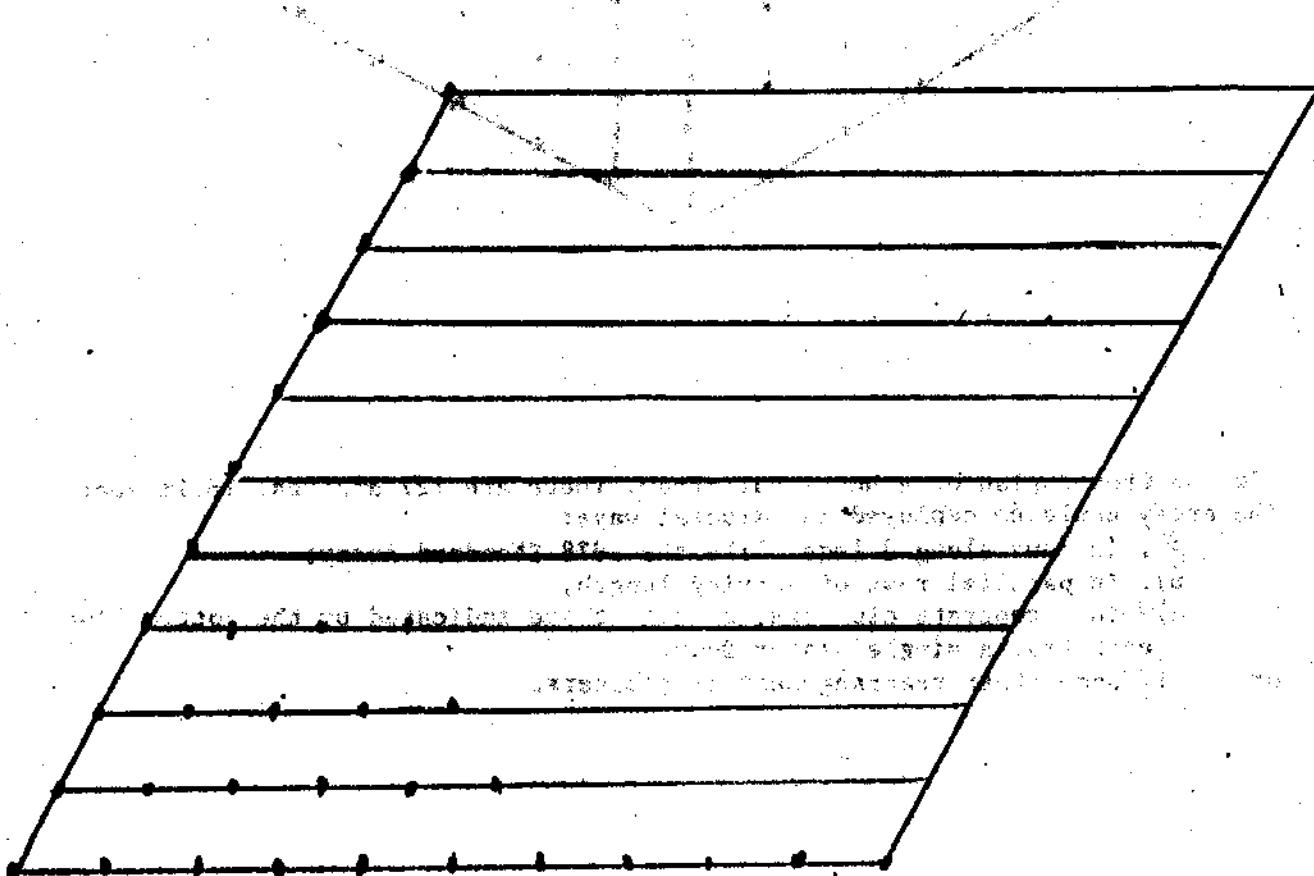


Fig. 1. Ground plan of cubic array, 150m on a side, 15m spacing between rows, strings.

Fig. 2 (below.) Ground plan of rhombic array, 162m on a side, 16.2m spacing between rows, strings. Area is same as Fig. 1, above.



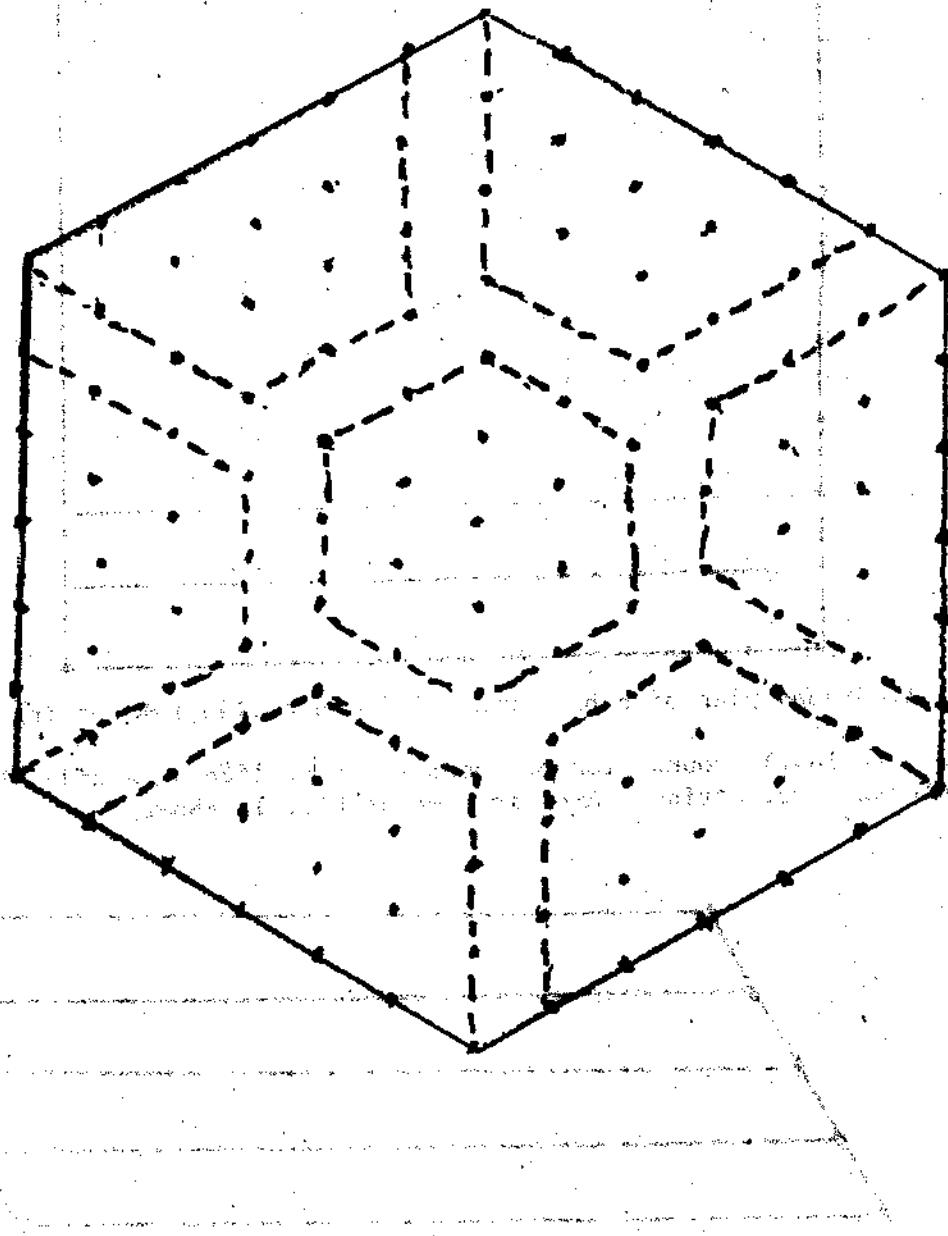


Fig. 3. Ground plan of a hexagonal array. There are 127 strings, 16.1m apart. The array could be deployed in several ways:

- a). in rows along 3 legs, like the 1978 Standard Array;
- b). in parallel rows of varying length,
- c). in 7 separate clusters, as e.g. those indicated by the dotted lines, each from a single Master Buoy,
- or d). some other rearrangement of clusters.

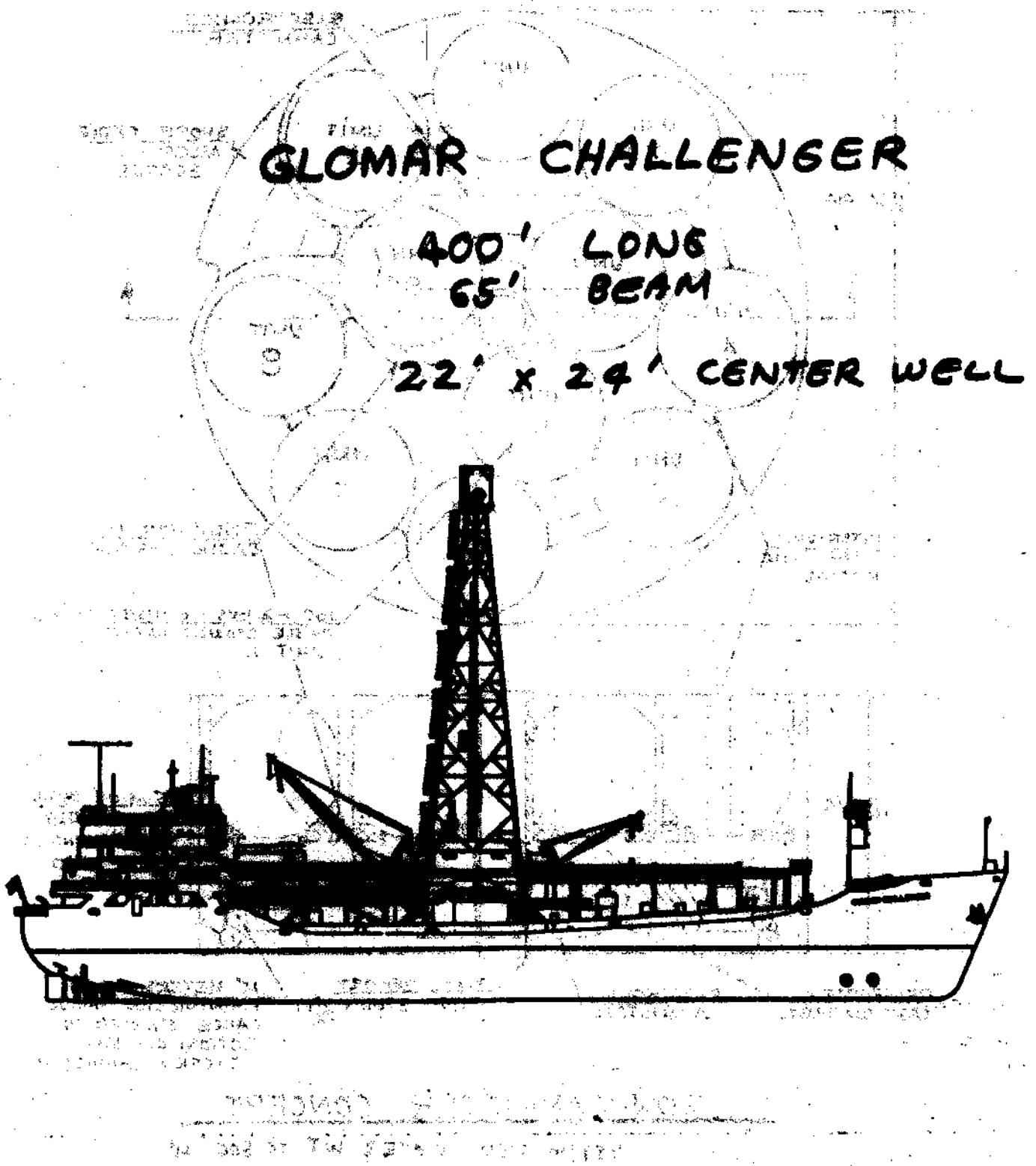
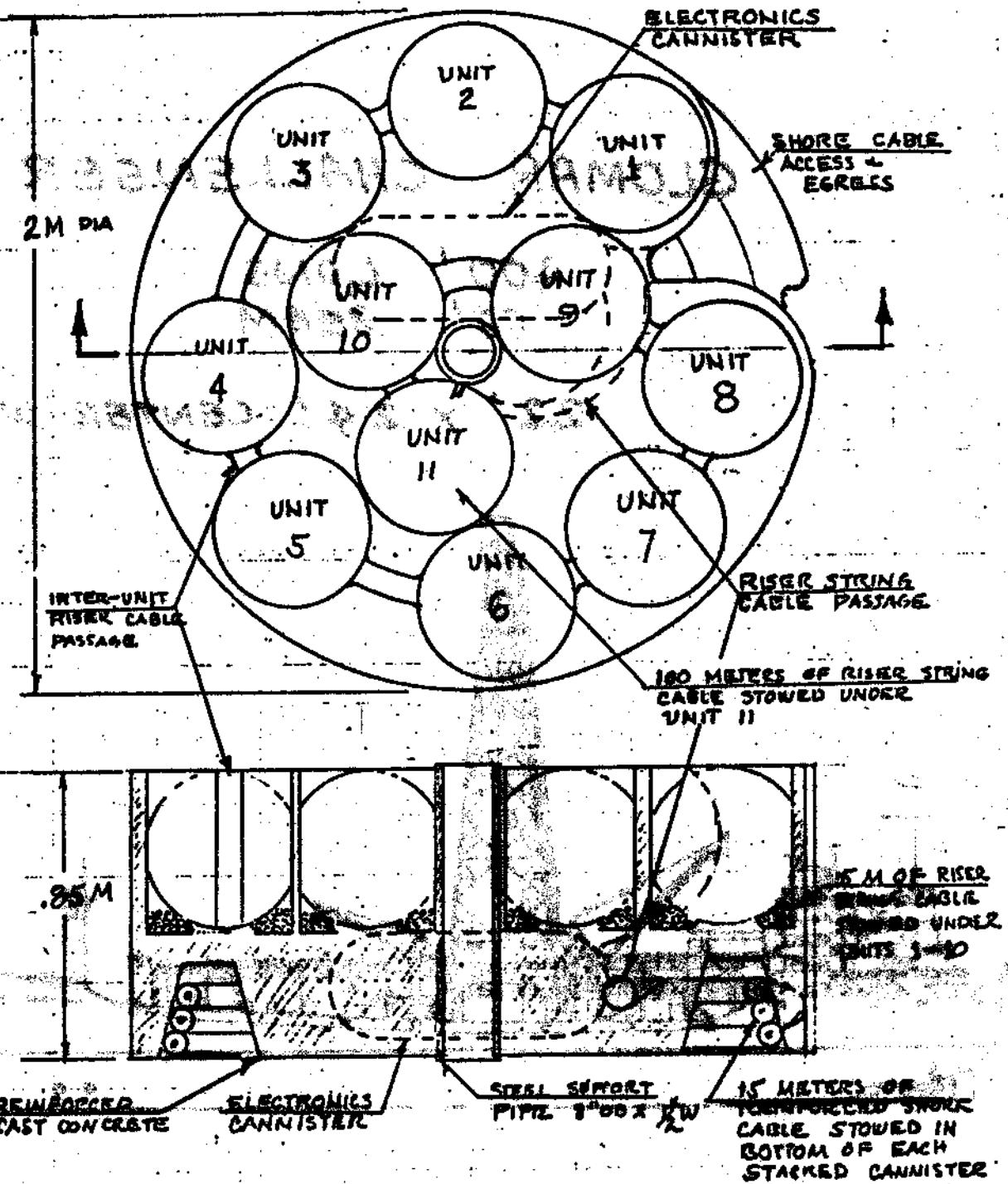


Fig. 4. Drill Ship, equipped with central well (moon pool), tower and winch, for deploying drill-pipe strings.



LOW CANNISTER CONCEPT

ESTIMATED WATER WT \approx 800 LB.

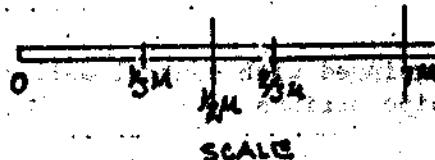


Fig. 5. Design of canister ("bagel") for string-of low-sensitivity optical modules (glass spheres with phototubes inside.)

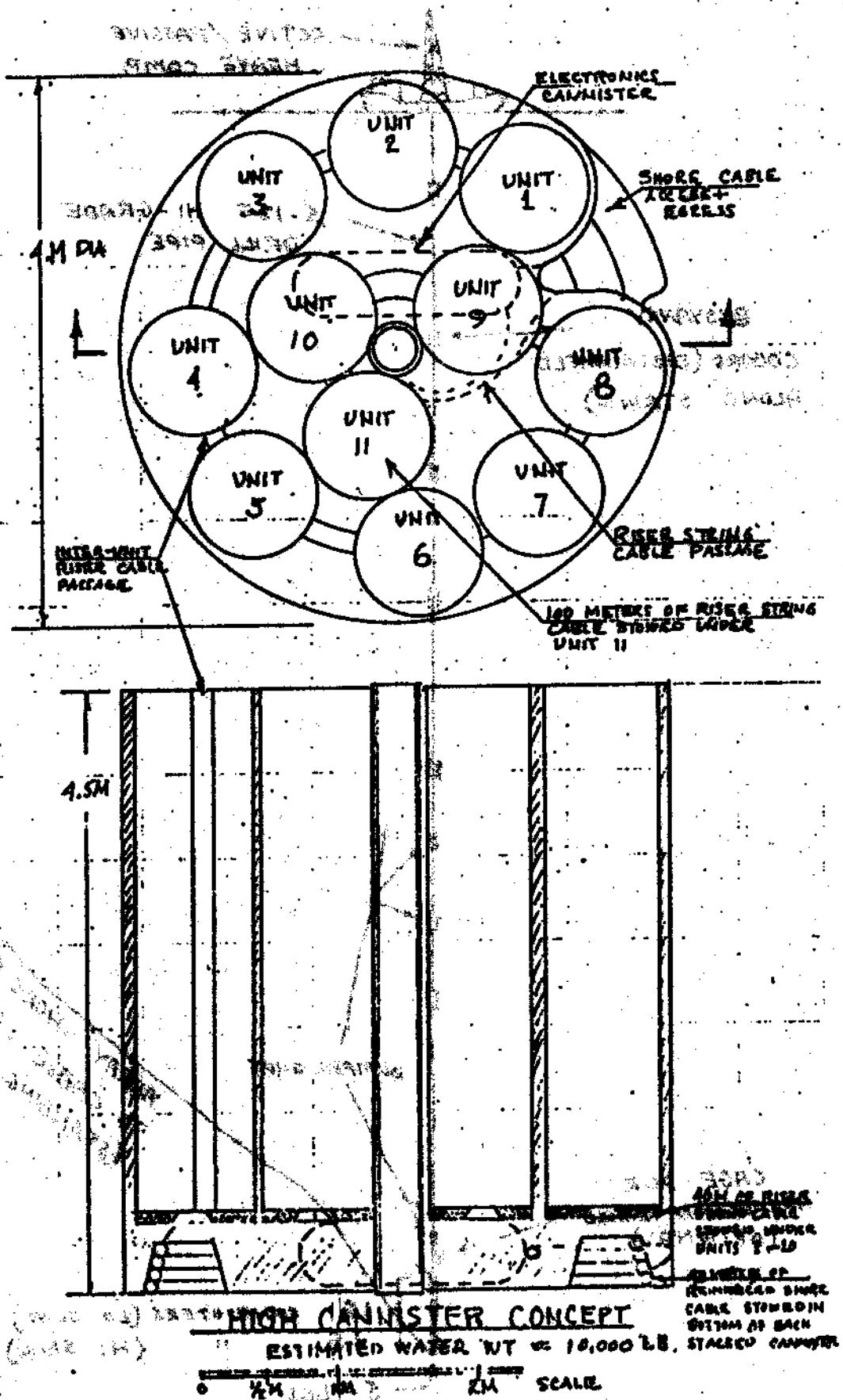


Fig. 6. Design of canister for string of high-sensitivity modules (Sea Urchin), each packaged into a cylinder 4m long, 1m diameter. The central holes in the beigel design are for the drill-pipe support, which develops a vertical transmission line that runs back to back to back to the base of the cylinder.

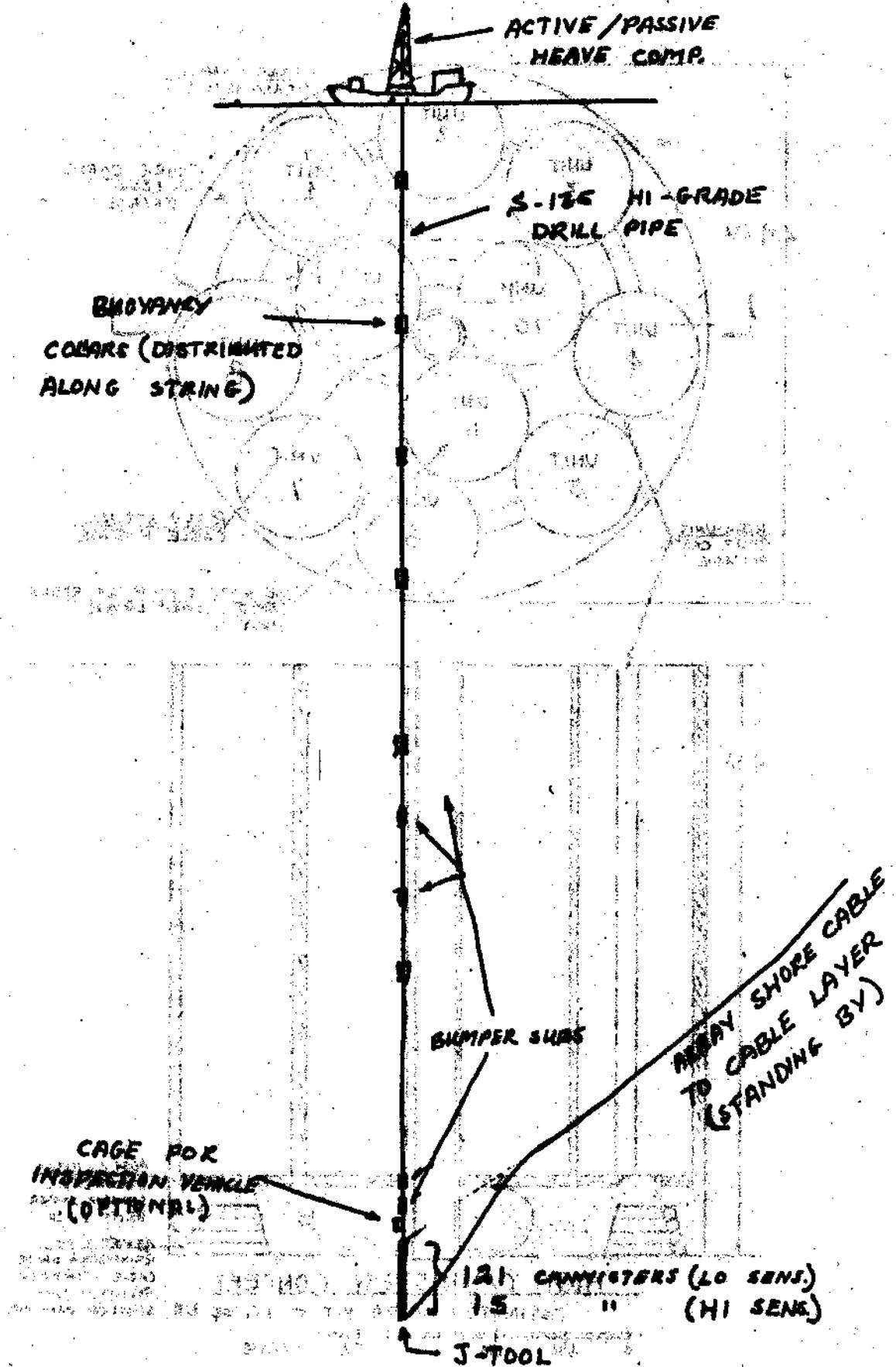


Fig. 7. Drill string deployed from drillship, with 121 canisters (low sensitivity) or 15 (high sensitivity) loaded on string, ready for deployment.

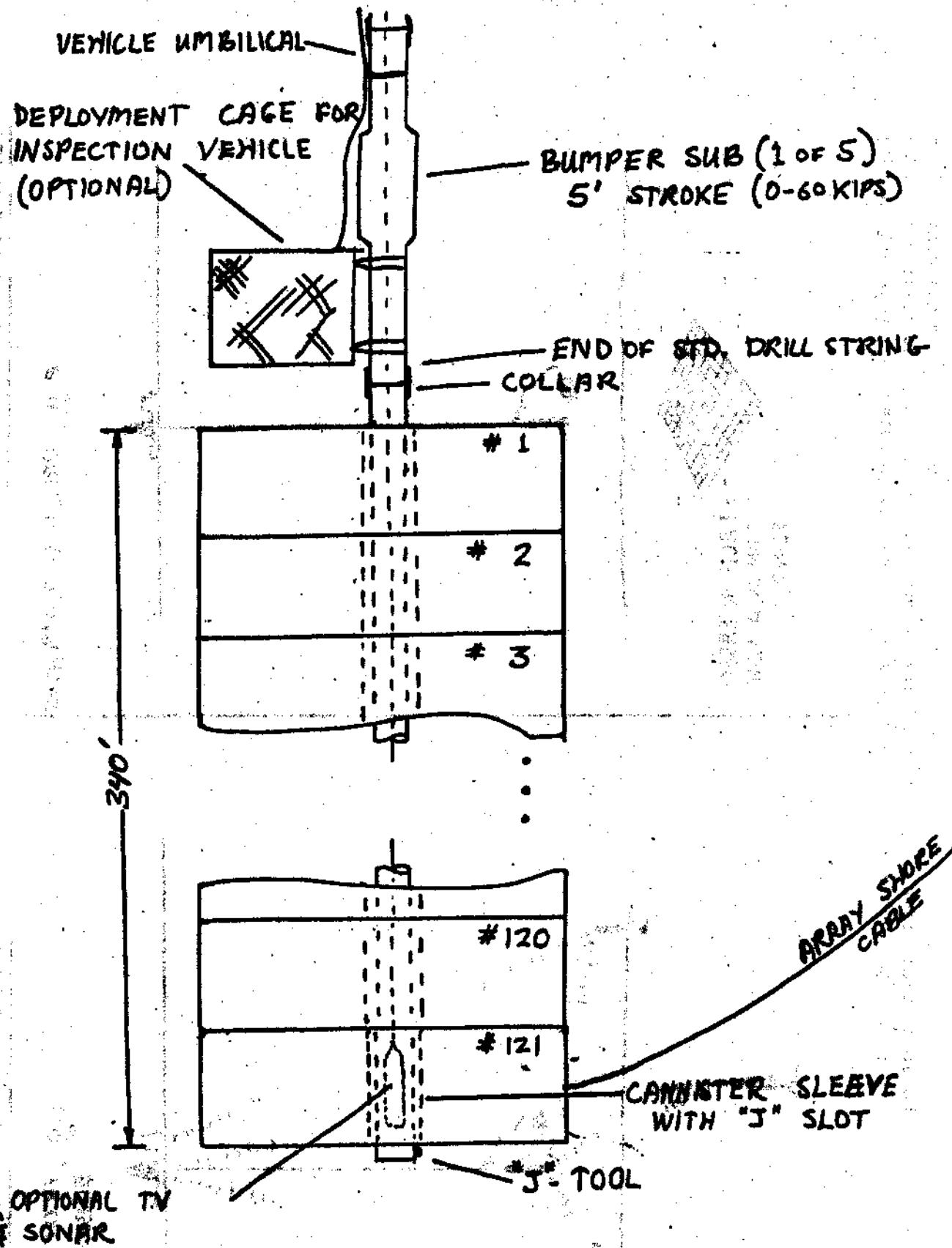
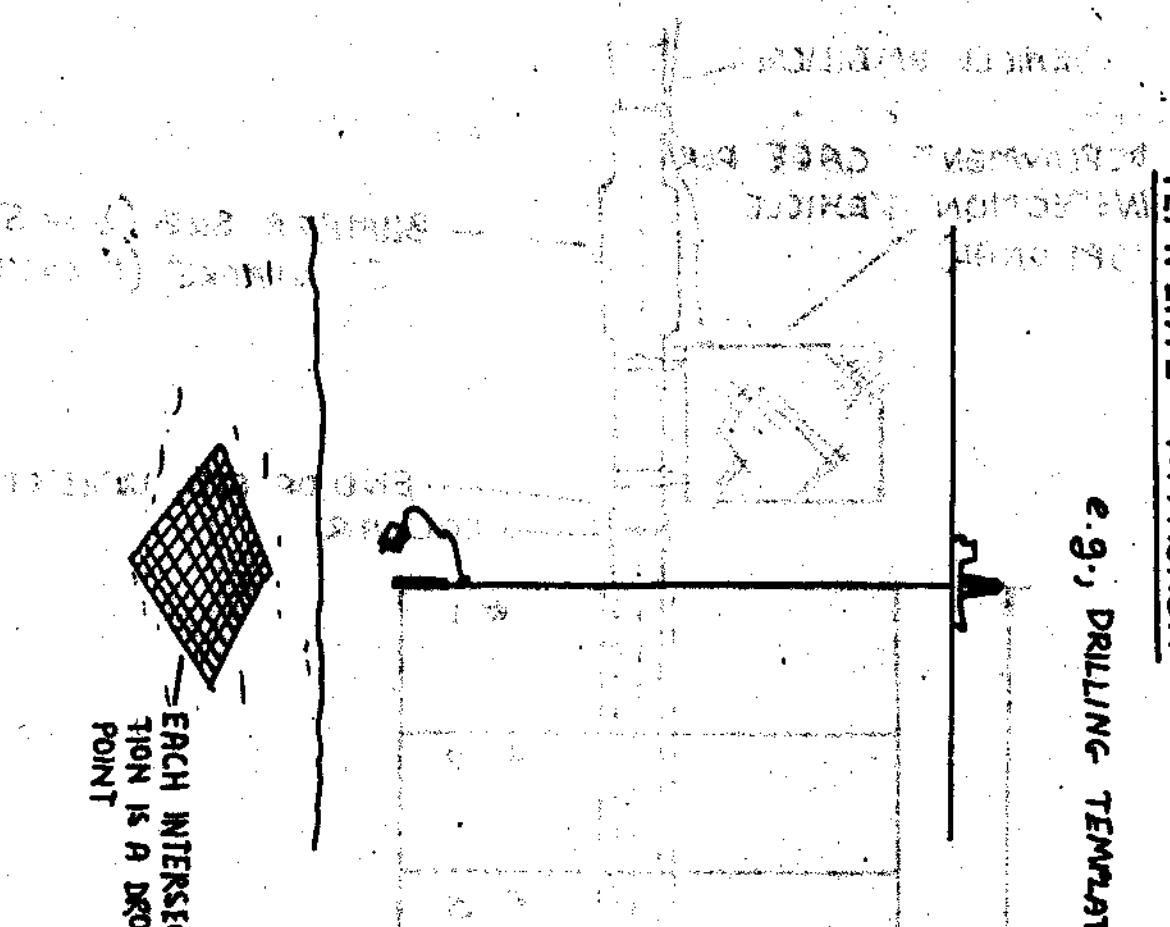


Fig. 8. Detail of loaded drill string, showing some of the auxiliary equipment used.

TEMPLATE APPROACH

e.g., DRILLING TEMPLATES



DOTS APPROACH

e.g., ACOUSTIC NAV. OF SUBMERSIBLES

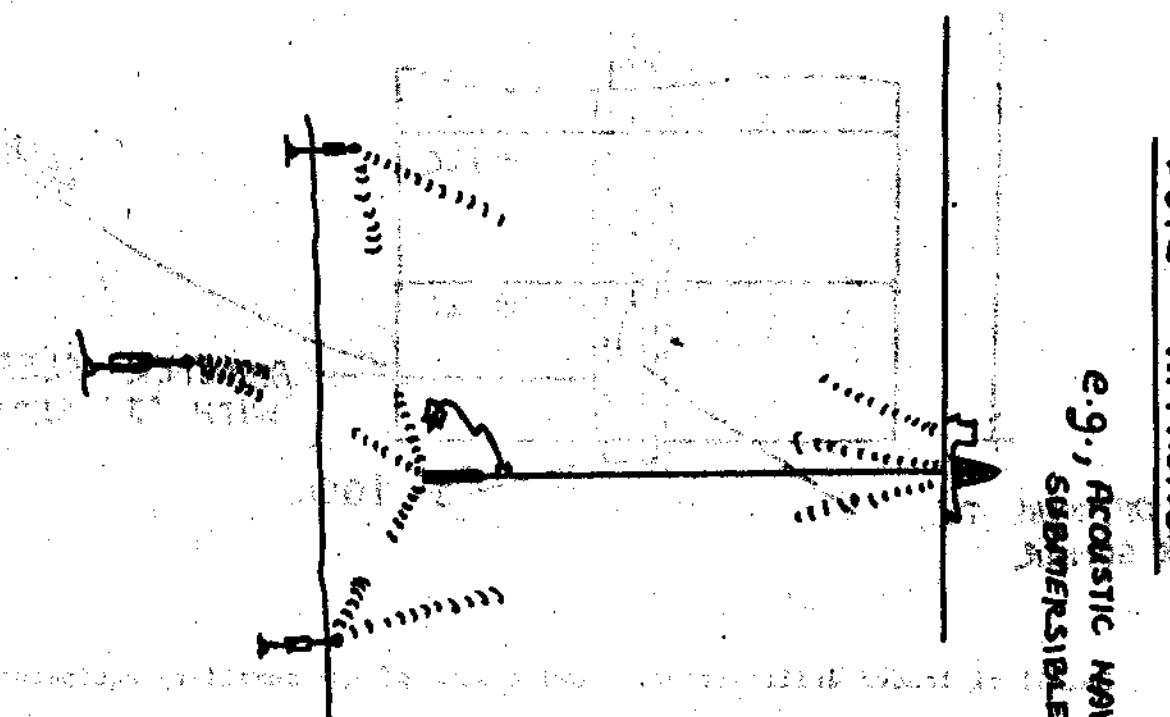


Fig. 9. The actual emplacement process is carried out with the aid of either a) a coordinate grid, or b) a virtual coordinate grid produced by acoustic interrogation of transponders on the bottom.

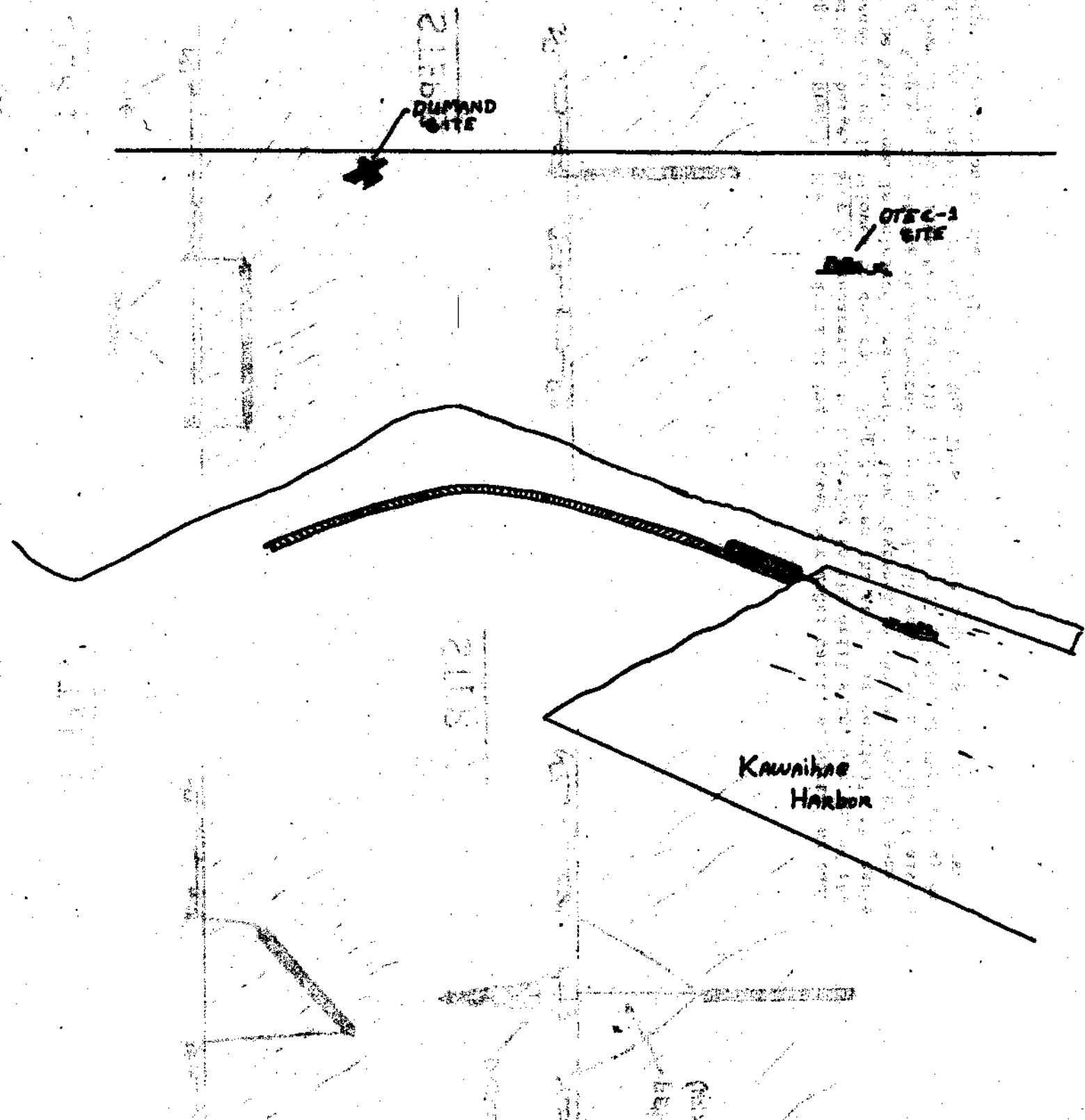


Fig. 10. Proposed mode of assembling the bagel on a section of drill string on land, and then launching it with a railroad system and a tug. The flotation system for the drill string is not shown.

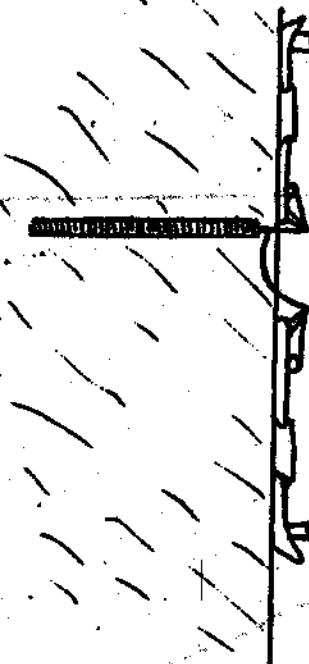
STEP 1

BARGES

TUG



STEP 3



STEP 2



STEP 4

PENANT LINE
(PIKE ROPE)

DRILL SHIP

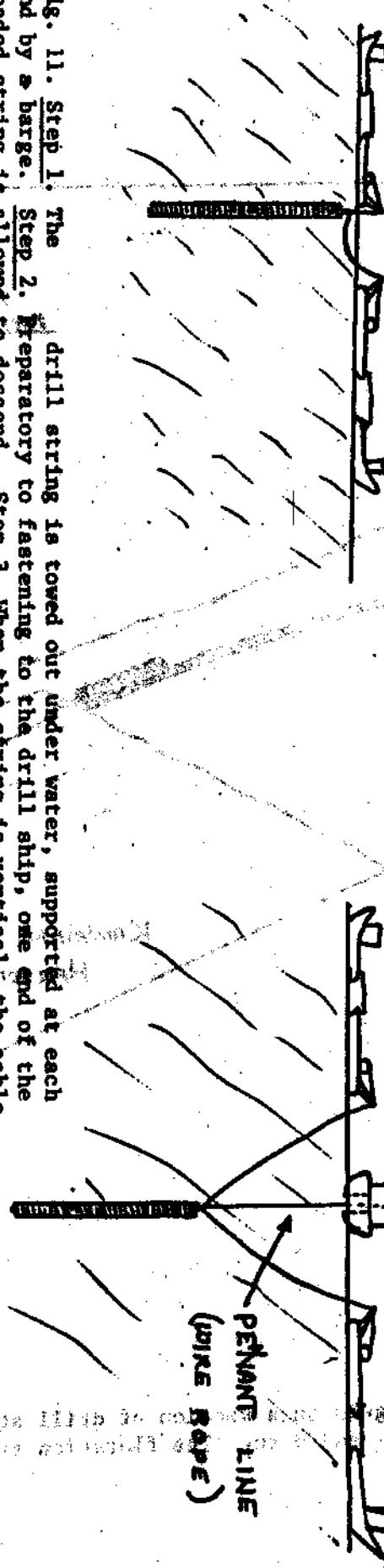


Fig. 11. Step 1. The drill string is towed out under water, supported at each end by a barge. Step 2. Preparatory to fastening to the drill ship, one end of the loaded string is allowed to descend. Step 3. When the string is vertical, the cable at the bottom end is released, and another line fastened to the top from the same tug. Step 4. The string is maneuvered under the drill ship, and a couple of divers go down to fasten a line from the drill ship to the drill string, so that it may be raised and attached to the drill string. This procedure requires two tugs and two barges in addition to the drill ship.

MASTER BUOY MICRO(MILLI-)ARRAY

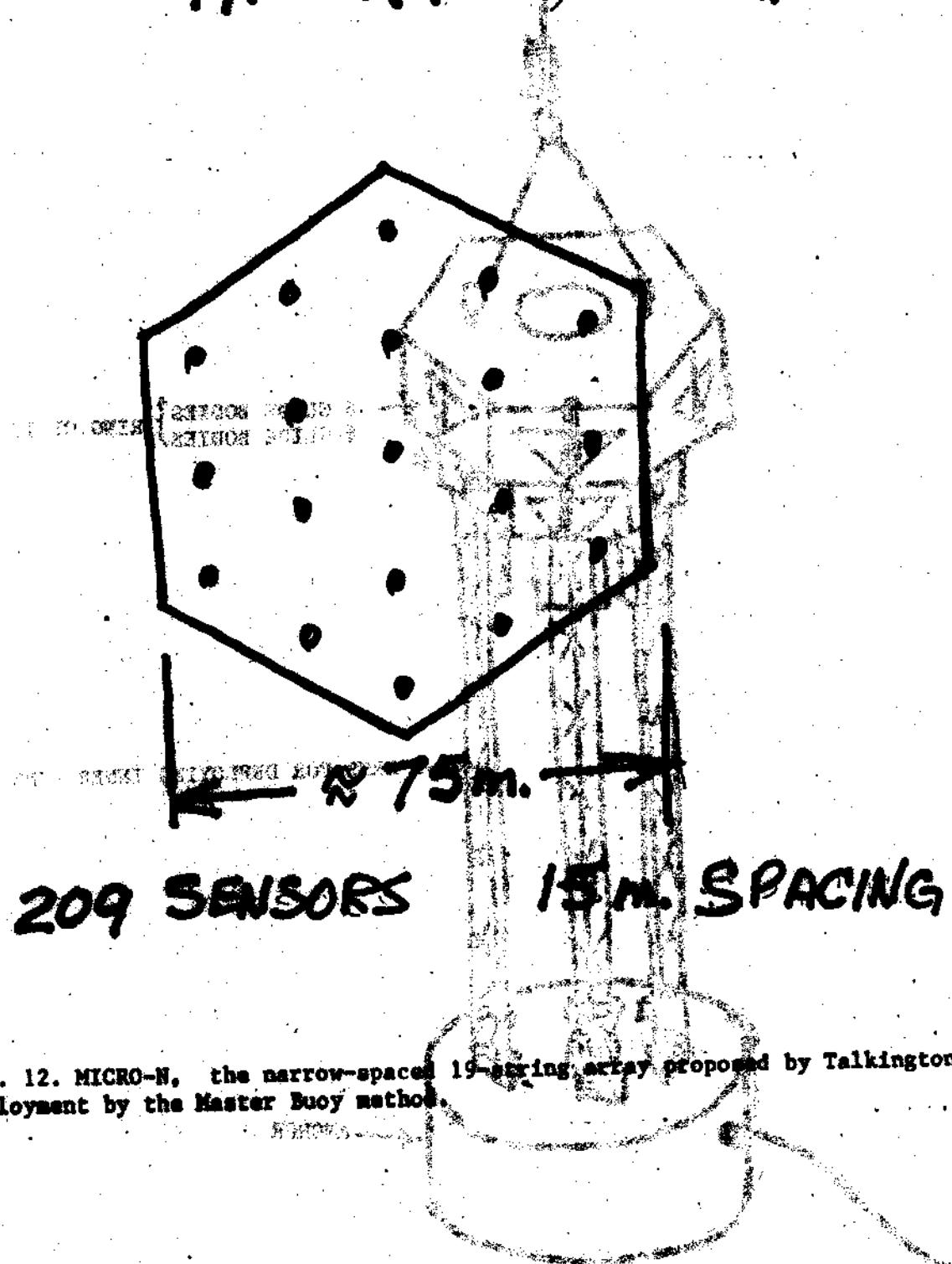


Fig. 12. MICRO-N, the narrow-spaced 19-sensor array proposed by Talkington for deployment by the Master Buoy method.

the central cell and sensors at the vertices of the array, and revision to the array size to 19 sensors. The array was modified and given the name MICRO-N. Sensors between adjacent cells were placed in a staggered grid to prevent interference between the signals from the individual cells. The array was deployed in the ocean off the coast of South Africa during October 1973, and eight separate measurements were made. The array was suspended from a master buoy which was anchored to the seabed.

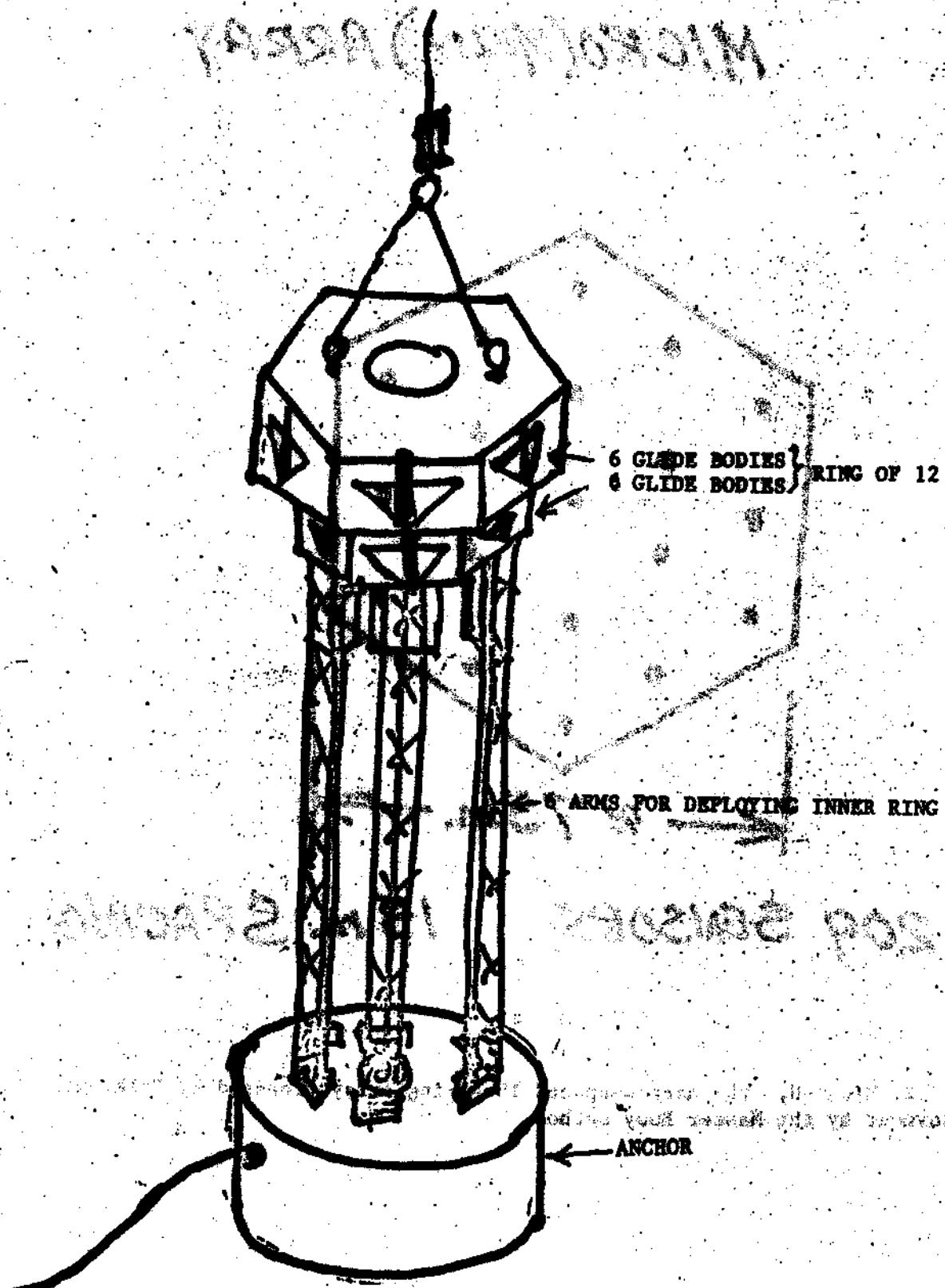


Fig. 13. Sketch of a master Buoy loaded with 19 strings, as it would be for lowering to the bottom. The central string, not shown, sits on the bottom anchor. Six vertical arms, in hexagonal array, carry the inner ring of six canisters. At emplacement time, the arms swing down and deposit their canisters accurately on the bottom at a fixed and predetermined distance from the center. Above, on two different levels, twelve guide bodies are poised to make their flights to the proper outer ring positions.

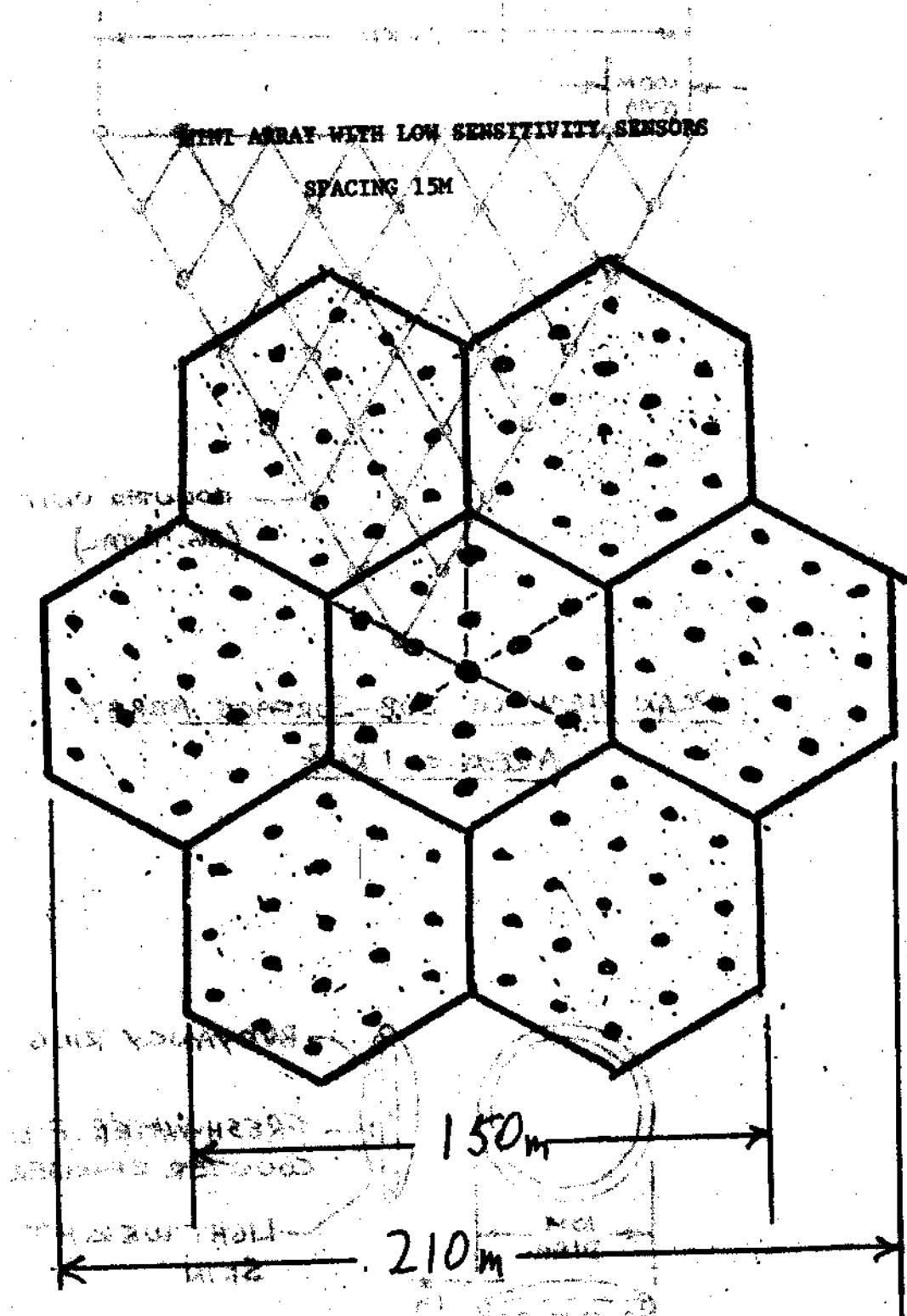


Fig. 14. This indicates the concept of using the Master buoy concept to deploy a large array like MINI, with seven hexagons, each containing 19 strings, deployed one at a time by a Master Buoy.

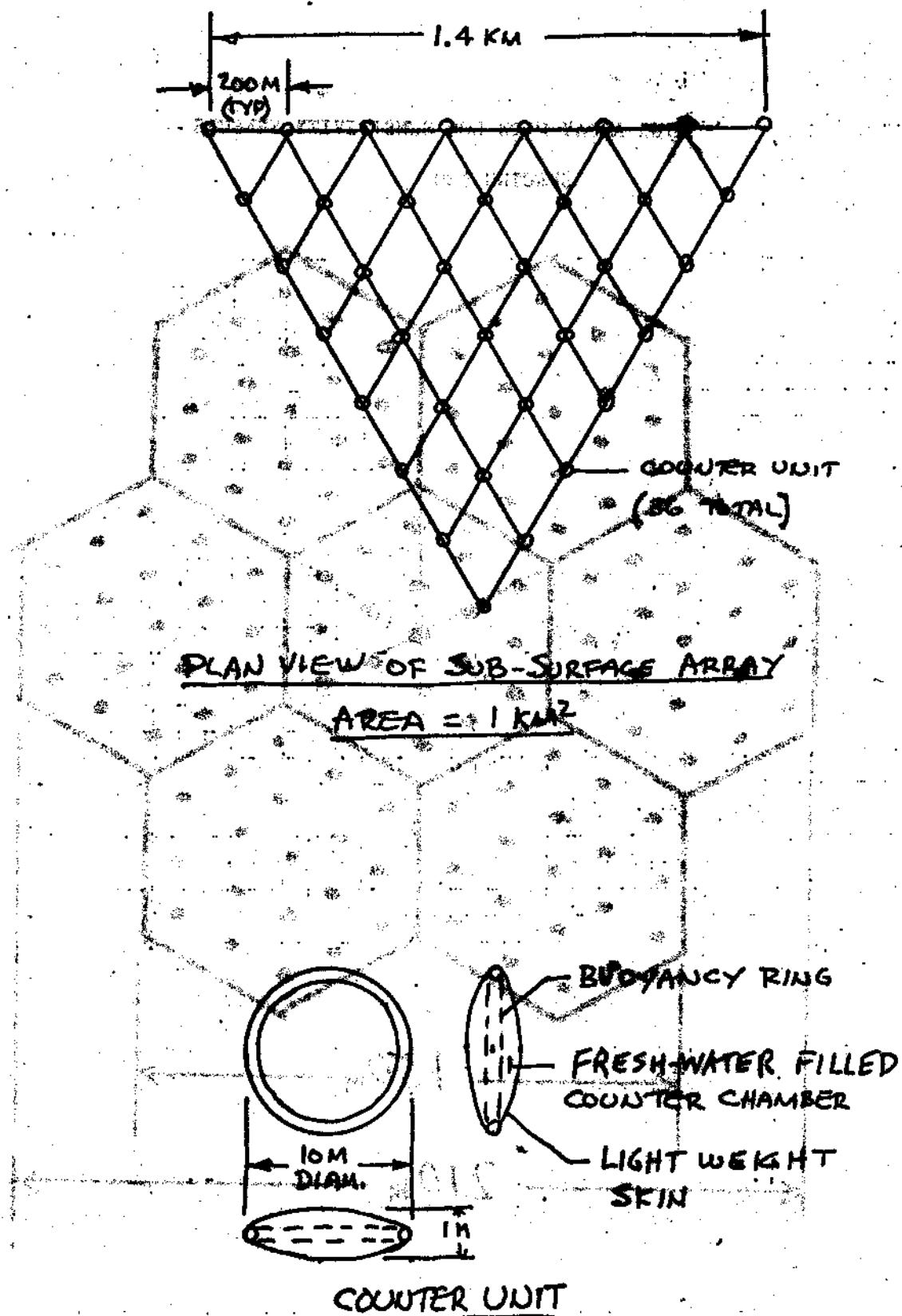
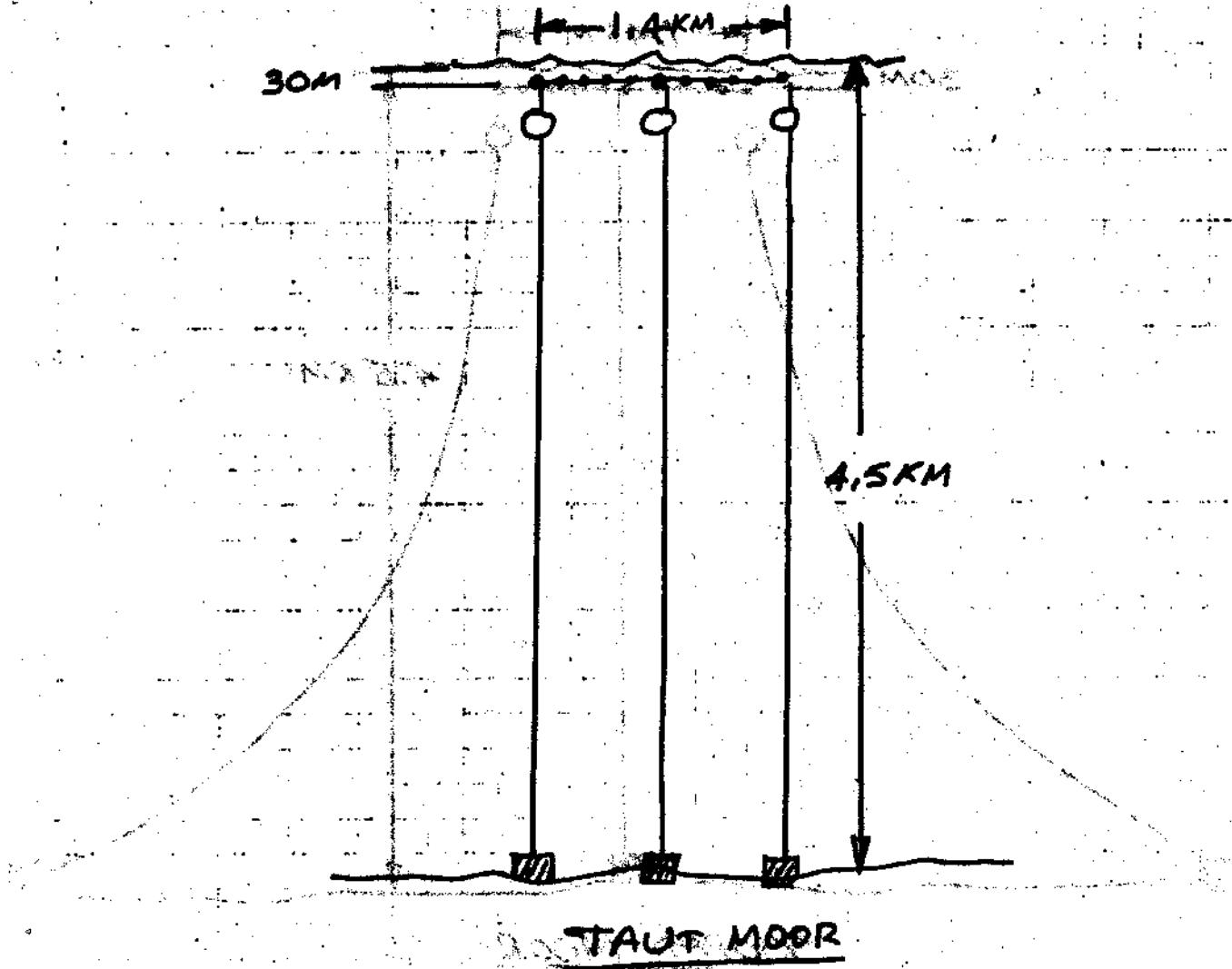


Fig. 15. Triangular matrix for a subsurface shallow array. The matrix, 1400m on a side, holds 36 sensors at the nodes of a hexagonal network with element 200m. Each sensor is attached to a node of the network, and maintains itself at the proper depth.



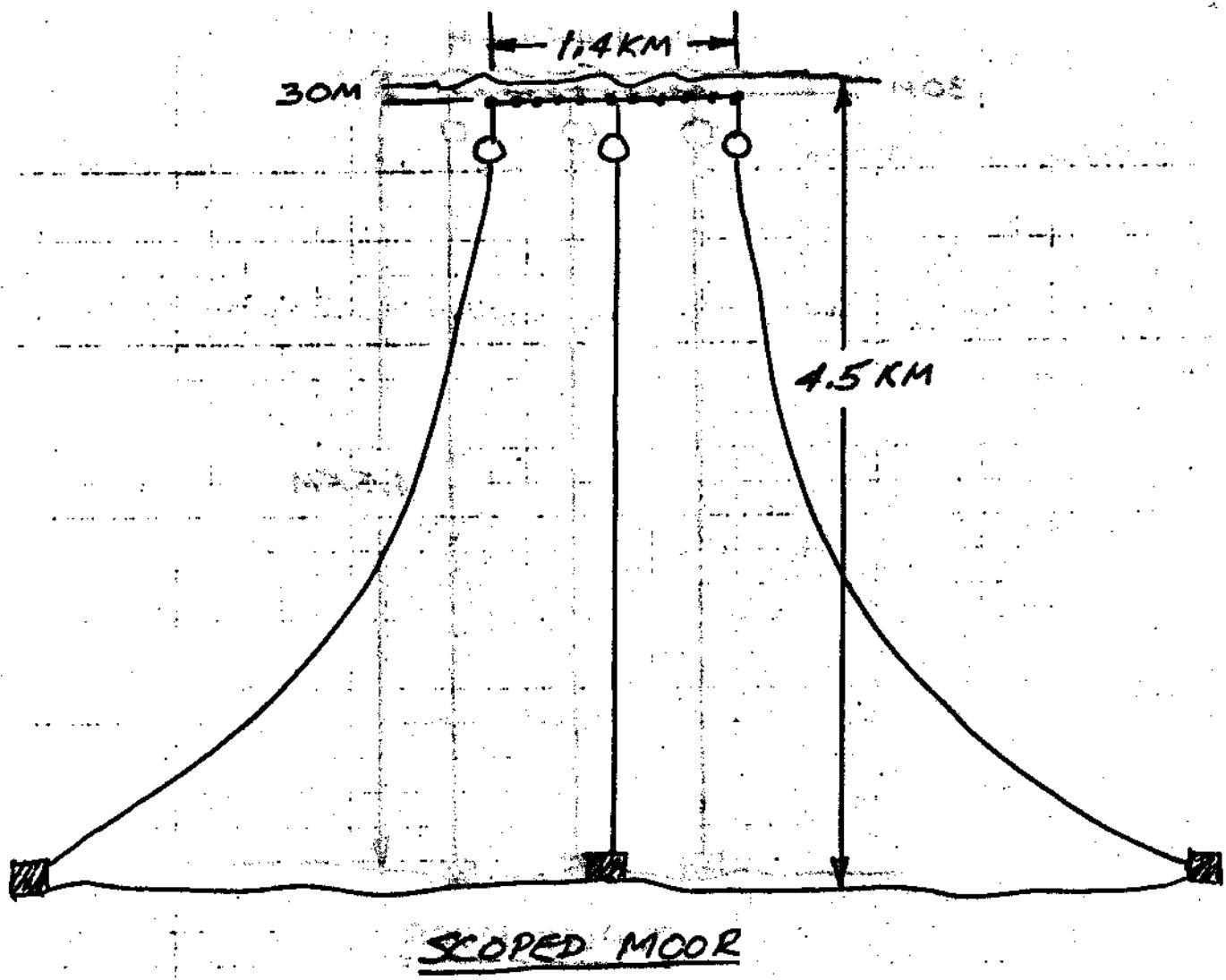
ADVANTAGES

- STAYS OVER SAME BOTTOM AREA
- LESS MOORING LINE
- EASIER TO INSTALL

DISADVANTAGES

- REQUIRES STIFFENERS BETWEEN OUTSIDE UNITS
- PRECISE IMPLANTATION
- HEAVIER ANCHOR SYSTEM
- COULD TWIST ON SELF
- TEND TO TILT ARRAY

Fig. 16. "Taut" mooring method of deploying the triangular sensor area,



ADVANTAGES

- LESS STORM AFFECTED
- LESS ARRAY DISTORTION
- CAN BE EMPLANTED
DIRECTLY OVER
BOTTOM ARRAY

DISADVANTAGES

- LARGER WATCH OVER
BOTTOM ARRAY
- DIFFICULT TO GET SUB-
SURFACE BUOYS SPACED

Fig. 37. "Scoped" mooring scheme.