DUMAND-2-92

Applications of Videoconferencing and Multi-Media to DUMAND*

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April 3, 1992

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*Submitted to Computing in HEP '92, Annecy, France.

Abstract

Several years in the making, DUMAND is now readying for deployment. This unique high energy neutrino telescope will be located 4.8 kilometers below the surface of the Pacific Ocean about 30 kilometers west of the town of Kona on the Big Island of Hawaii. Data will arrive from the PMTs, environmental modules and other electronics to a Shore Station located at the Hawaii Natural Energy Lab at Keahole Point. We are currently investigating applications and limitations of utilizing videoconferencing between the Shore Station and the University of Hawaii in Honolulu on the Island of Oahu for deployment operations, remote monitoring and conferencing; the latter to cut down both travel and phone costs by multiplexing data/video and voice over a single line. Our Multi-Media effort will center initially around a historical non-linear surrogate travel concept in cooperation with the Bishop Museum. We hope to achieve two major goals with this technology: Provide a laser disk outlining the major milestones and expected discoveries that DUMAND will engender and USE this technology as a basis for future remote monitoring and event reconstruction. We hope to provide a scaled down visual/audio display with a narrative outlining both the technology its requirements and limitations and our projected goals.

1 Preface

DUMAND, the Deep Underwater Muon and Neutrino Detection, is an experiment composed of physicists from the following universities: Aachen (Germany), Bern (Switzerland), UCSD (Scripps), Hawaii (Manoa), Kiel (Germany), Kinki, Kobe, Tohoku and Tokyo (Japan), Vanderbilt (Tenn.), Washington (Seattle), LSU, and Wisconsin (Madison). A further tie-in with the similar but not as advanced NESTOR project in Greece, is currently being investigated.

DUMAND's purpose is to explore the universe in a new light, not as we traditionally expect by photons, as with normal telescopes, but through neutrinos. The detector will be located off the coast of the Big Island of Hawaii and the experiment is due to begin taking data in 1993.

DUMAND represents one manifestation of a much heralded convergence between particle physics, looking at the infinitely small, and astrophysics and cosmology examining the universe on the other extreme of the size scale.

2 DUMAND an Overview

The DUMAND Neutrino Telescope consists of 16 inch diameter photomultiplier tubes (PMTs), placed in spherical glass housings which can withstand the ocean pressure (see fig. 1). There will be 24 PMTs per string and thus 216 for the 9 string array (see fig. 2 and 3). At the depth of DUMAND operation, 4.8 km (15,000 feet), the pressure is about 500 atmospheres, so pressure resistance posed a major engineering challenge, now well understood. The optical detectors will be placed in vertical instrument strings 350 meters tall (1000 feet), floating up from the ocean bottom. The array now being built will have nine strings, eight around a (imaginary) cylinder 100 meters (300 feet) in diameter, and one in the center. There will also be 45 hydrophones, for purposes of acoustically surveying the array (and listening for some rare phenomena), and 15 laser calibration units, needed to monitor the sensitivity of the optical detectors and to calibrate their timing to nanosecond levels. The various modules in a string all communicate via fiber optic links to an electronics package at the bottom of each instrument string. This unit will contain an application specific digitizing chip which will record the arrival of light pulses with a precision of one nanosecond. The data and other control signals from an entire string is then multiplexed onto one single mode fiber link to the Shore Station approximately 30kms distant (see fig. 4).

The array will be lowered one string at a time from a surface research vessel, and connected to a cable to shore by a manned research submarine. The junction box at the end of the cable will have various instrumentation, including television to monitor emplacement and connection activity. The shore cable will be layed in late 1992. It will come ashore at the Natural Energy Laboratory of Hawaii, located at the western-most point of the Big Island of Hawaii, near the town of Kona. In this laboratory the data will be received from the 10 data carrying fibers (one for each string plus one for environmental data) at 625 Mb/s. Filtering will then reduce this to a final data rate of 80Kb/s.

Power will be sent down the 1.5 cm diameter armored cable at high DC voltage, delivering 5.5 kilowatts to the array. The fibers carry commands out to the array as well as data and status information back to shore, 1300 nanometers incoming to the array and 1550 nanometers outgoing. Because the array will contain about 250 network linked computers, which can control many functions such as voltages and switches, the array can be remotely tuned and even reprogrammed to cope with the unexpected, or to deal with failures (strings can be replaced in case of major failures, but this is expensive). The array will be operated sequentially by teams of physicists on shift in Hawaii, Japan, Europe and the mainland U.S.

3 Project Outline

3.1 Phase 1. Visualization of the DUMAND experiment through multi-media

The first problem is an effective visualisation of the experiment. The detector array is extremely well shielded from view, being in the deep ocean; and through its sheer sise and low density would even be fairly hard to overview if it could be shown on land. Visualizing the detector is a problem, both for the physicists working with the data, and for outsiders. There are several demands and uses for describing and visualizing the scope of the project, we will list some of them:

The DUMAND project will have a visitor center at the Keahole laboratory site, analogous to MicroCosm at CERN. Some of the visitors will be tourists with an interest in science; the lab site is very close to the resort area of Kailua-Kona; and the visitor center for the telescopes on Mauna Kea (located at the astronomy mid-level facility) is a popular tour stop. At the other end of the spectrum of Lab visitors will be the VIPs from the scientific and funding areas.

The project will have high visibility locally, nationally and internationally, being a keystone of Hawaii's science program, the largest astro-particle project in the US, and an international collaboration spanning several European countries, the US and Japan. Unfortunately, all that is "visible" is the laboratory area, with the control computers and the electronics setup.

There are clear demands and opportunities for demonstrating the project, its design and intent. We expect to use these opportunities to further the progress of neutrino astrophysics. However, as outlined above, this demonstration is fairly difficult due to its extraordinary scope. We hope to remedy this by the following methods:

- video footage of components of the experiment being constructed and deployed,
- computer graphics of the array and its operation, showing typical or even the current data as it is gathered from the array, for which we can use an event-display program,
- video footage of deployment operation and parts of the array from the video cameras used underwater. The environmental sensor package used on the junction box at the end of the electro-optic cable is equipped with several cameras, and the remotely-operated undersea vehicles used for installation of the pieces of the array have online high-quality video cameras,
- narrative to integrate this visual information and available in a choice of different languages.

To achieve these goals without spending an extremely large amount of time and money we can only think of computer-based multi-media demonstrations. We would like to set up a system to archive a library of relevant information in compact disk form, select a software platform which will allow us to most easily integrate video and graphic images etc... and use a low cost multi- media display hardware platform. A further feature of this technology, is its non-linearity thereby allowing us the freedom to navigate across 54,000 individual frames (for a 30 minute disc) which are, via software activated icons, linked into selected segments. These will provide access to, for example, the role ocean based technologies have had on this experiment, the motivation for neutrino research or an interview with pertinent researchers.

3.2 Phase 2. Video conferencing between array, shore station, and ship

For the deployment operation we currently have two options. The first one is via a Manned Submersible (such as the USN Sea Cliff, see fig. 5) and the backup is via a Remotely Operated Vehicle (ROV) (such as the ATV or Gemini II). There are only a few manned or tethered submersibles in the world capable of operating at depths of over 4.5 kilometers. The reason that the manned submersible is our first choice is simply that the risk of having a tethered vehicle's line snag on the array is relatively high. Current meters were deployed in March of this year and their data, when they are retrieved in September will provide useful information as to current speeds and patterns at the bottom. These submersibles, will perform the tasks of connecting the array substrings to the electro-optic cable. This is a fairly complicated process performed 4 kms. below the Ocean surface. The electro-optic cable ends in a junction box on the sea-floor, which is equipped with several high-quality video cameras and environmental sensors to help guide the operation. Also, the sonar positioning system built into the detector array will be used by the submersibles for navigational purposes. All this information emerges from the electro-optic cable at the shore station laboratory.

Should we decide to use the ROV, and in order to optimally control the ROV during this difficult operation, we would like to be able to transmit the information from the shore station laboratory to the ROV control center onboard the ship, in a fashion which allows the ROV operators easy access to the information. Currently we foresee the use of a simple voice radio, through which the information from the seafloor systems is relayed by messages from ancillary operators observing the video and data from the shore station. Since the distance between the ROV support ship and the shore station is fairly small (about 20 miles) a microwave computer network link of reasonable speed could be set up to communicate with the ship. In the best of all cases, the digital information from the seafloor sensor systems would be pre- processed into computer images. This video information from the seafloor camera systems, and an audio channel would then be transmitted to the ROV control center aboard the ship. Feedback information from the ship would be required to position and adjust the camera systems.

Since the aggregate data rate from computer graphics, several video channels, audio information, and feedback will most likely exceed the capacity of the data channel between ship and shore, image and data compression techniques will have to be employed on both ends of the link. Current compression technology is expected to be around 30:1 by year-end which should allow a microwave based system operating at ethernet speeds to provide near real-time 30 frames/sec images.

3.3 Phase 3. Intercontinental remote monitoring and control of the detector

Traditionally in astronomy and high-energy physics experiments, physicists operated the equipment directly and manually. In the case of classical experiments this has led to the need to have around-the-clock watch for the experiment.

In the case of DUMAND, such a direct operation is not sensible any longer. The experiment, once debugged and operating has no moving components, and no part of it can be mechanically adjusted or influenced. The data rate, after all the filtering and compression performed at the shore station laboratory, is low enough to allow the data to be stored on optical or magnetic media, or transmitted through networks to remote computers. We expect our weekly data rate to be around 6×10^9 bytes. However, there will still be need for constant monitoring and control. The operating parameters of such a complicated system in the deep ocean have to be continuously watched by a human observer, who has to be able to adjust the mode of operation.

However that duty ideally, does not have to be performed directly at the shore station. All equipment in the ocean is by definition only controllable remotely. No component or system at the shore will require manual intervention, excluding change of tapes or optical disks, which can be performed by personnel already at the site for other projects. All operations will be controlled and monitored through the main control computer system, with all functions centralized into one system control workstation. If possible we want to be able to run the experiment from remote locations and to such end we have standardized on portable code as well as vendor independent platforms (such as C and OSF/MOTIF) in order to present the same interface to remote operators. We are currently investigating various networking alternatives and their costs to link the shore station to the University of Hawaii as well as evaluating current connectivity to collaborating universities on the mainland of the USA, as well as to those in Europe and Japan.

For remote monitoring as well as video conferencing, the network path between between Hawaii and Wisconsin, for example, looks something like this (for both DECnet and IP)

$$Hawaii \leftrightarrow Ames \leftrightarrow LLNL \leftrightarrow LBL \leftrightarrow FNAL \leftrightarrow ANL \leftrightarrow WIS$$

$$(PACCOM) \qquad \longleftarrow (ESnet) \longrightarrow \qquad (CICnet)$$

The PACCOM link between Hawaii and Ames is 512Kb/s, but due to be increased to 768Kb/s. The rest of the path is full T1 (1.544Mb/s).

Table 1: DECspin Performance for 272 x 184 Black & White Frame

Network	One-Way/Two-Way	Compression?	Frame Rate	Data Rate (Mb/s)	Packets/s
Ethernet	→	No	9.4	3.7	~ 370
	↔		6.0	2.4	~ 300
	→	Yes	15.4	1.5	~ 190
	↔		11.0	1.1	~ 170
FDDI	→	No	12.4	4.9	~ 200
	↔		8.8	3.6	~ 180
	→	Yes	19.6	1.9	~ 135
	↔		13.4	1.3	~ 120

Table 2: DECspin Performance for 272 x 184 Color 24 Bit Plane Frame

Network	One-Way/Two-Way	Compression?	Frame Rate	Data Rate (Mb/s)	Packets/s
Ethernet	→	No	3.2	5.0	~ 450
	↔		2.0	3.0	~ 320
	→	Yes	7.0	2.7	~ 280
	↔		5.0	1.8	~ 200
FDDI	→	No	4.2	6.6	~ 220
	↔		2.8	4.4	~ 180
	→	Yes	8.6	3.4	~ 130
	↔		6.0	2.2	~ 110

The two network alternatives being considered between the shore station and the University of Hawaii are:

- One 56Kb/s line for voice and data. This line would go from the shore station to Kona and from there via digital microwave to the summit of Haleakala on the island of Maui (line of sight) and repeated to Honolulu
- One T1 line carrying either one video channel, or multiplexing two voice lines and several data lines, via the same route as above

Currently Hawaiian Tel recommends a dedicated 112kb/s (2x 56KB/s) line for video-conferencing. However, from the tests conducted at CERN as part of the DECSpin, Digital Equipment's video-conferencing product, Field Test we observed the figures in Tables 1 and 2 above.

* How data was obtained:

```
Observed Frame Rate:     "Status" window in DECspin
Data Rate:               "Status" window in DECspin
Packet Rate:(*)          netstat -I fza0 1  (FDDI)
                         netstat -I ln0  1  (Ethernet)

(*) Values were confirmed by network monitors
```

* System Load Observations:

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CPU Utilization:         Ethernet:        ~30%-60% idle CPU
(vmstat 5)               FDDI:            ~ 1%-10% idle CPU

No Paging or Swapping Observed
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* System Configurations:

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2 x DS5000/200, 64MB Memory
Private Ethernet segment, FDDI fiber
Attached Ethernet and FDDI Monitors
```

* DECSpin Setup:

```
Frame Size:       272 x 184
Frame Rate:       Machine1: 30 frames/sec
                  Machine2: 30 frames/sec (<--> two-way )
                             0 frames/sec (---> one-way )
Compression:      Yes = 1/4 (software)

DECmedia Audioserver not running
```

4 Conclusion

Based on the performance figures above for DECSpin, and I would venture for similar offerings from other vendors, video conferencing over a WAN will not be achievable over a 56Kb/s line until such time as a programmable video compression system is incorporated into the design. Thus, if video conferencing has come of age on a LAN (preferably on an FDDI 100Mb/s backbone) or a "dedicated" ethernet it is still early days for a WAN. Indeed one would, from the figures above, require at least a T1 line for "near acceptable" video transfer rates. From the performance figures observed, we never achieved our goal of real-time 30 frames/sec video transfer. However, if stills are sufficient (2 to 3 frames per second and very small images at that) you can bring your network bandwidth requirements down to a bare minimum of 128kb/s. That is because DECSpin uses an uncompressed audio signal at 8kHz which requires a minimum of 64kb/s. Unfortunately for us, Hawaiian Tel only provides 56kb/s or T1 and moreover does not provide for fractional T1.

Although hardware compression is going to increase the quality of the image, and certainly an improvement over the PictureTel offerings over switched 56kb/s, the minimum network bandwidth required, for the forseeable future, will remain at 1Mb/s.

Given the current cost of such a line as well as the multiplexing equipment we would require ($30k) in order to use the bandwidth available for voice or data when video is not transmitted, makes it difficult for us, given DUMAND's current budget, to implement such a technology. We will thus begin with a 56Kb/s link from the shore station back to the University and will migrate, as financing, permits to T1. However, we will continue to monitor this technology closely as our need, given the geographic spread of our experiment, could really benefit from video-conferencing. Furthermore, we have received queries from another astrophysics experiment (CLUE) slated to deploy on Haleakala, Maui, in 1993 for video-conferencing and the feasibility of establishing a link between us and Pisa and/or Padua. Thus our interest in this technology will grow as Hawaii's preeminent role in the particle astrophysics area increases.

5 Acknowledgments

Such a paper represents the work of the whole DUMAND collaboration, nevertheless I would like to especially thank John Learned (Technical Director DUMAND) and Ralph Becker-Szendy (SLAC) for their help not only with this paper but also with this project. And last but not least Eric Gerelle (CERN-DEC Joint Project) without whose vision I would not have been able to partake in this challenging experiment, as well as Carola Clavi DEC-CERN Joint Project for providing the benchmark figures used in this report.

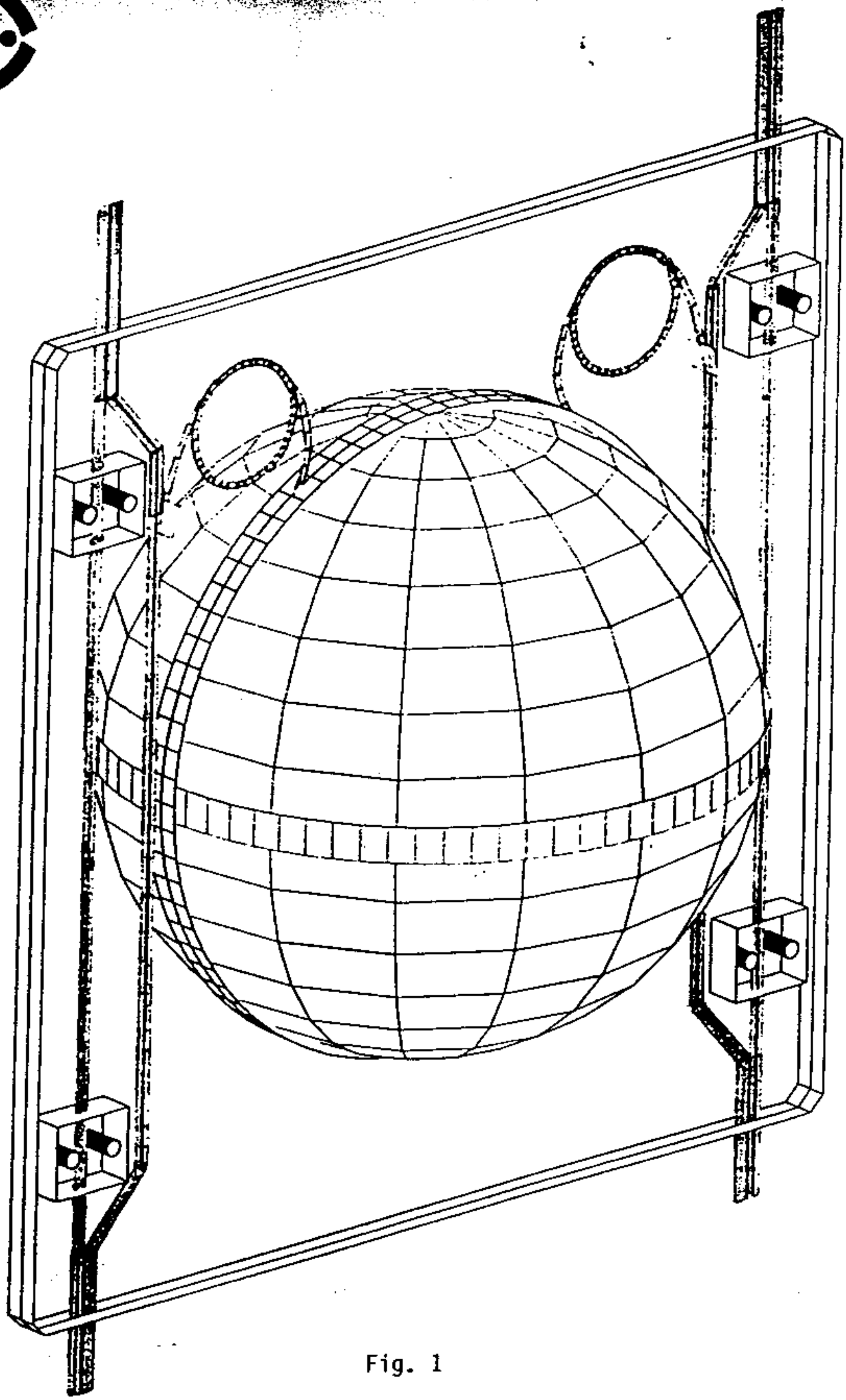

Fig. 1

DUMAND string

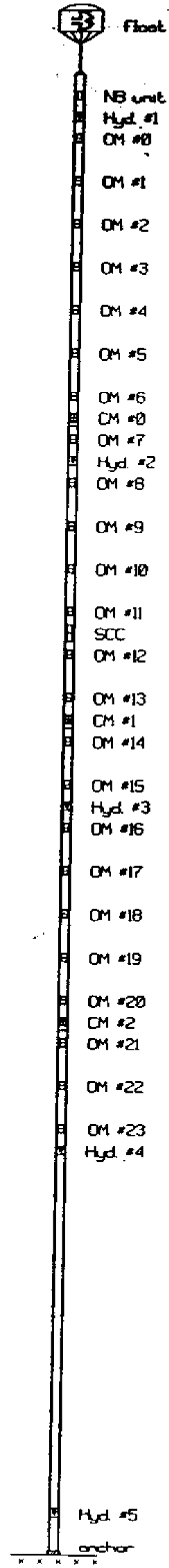

Fig. 2

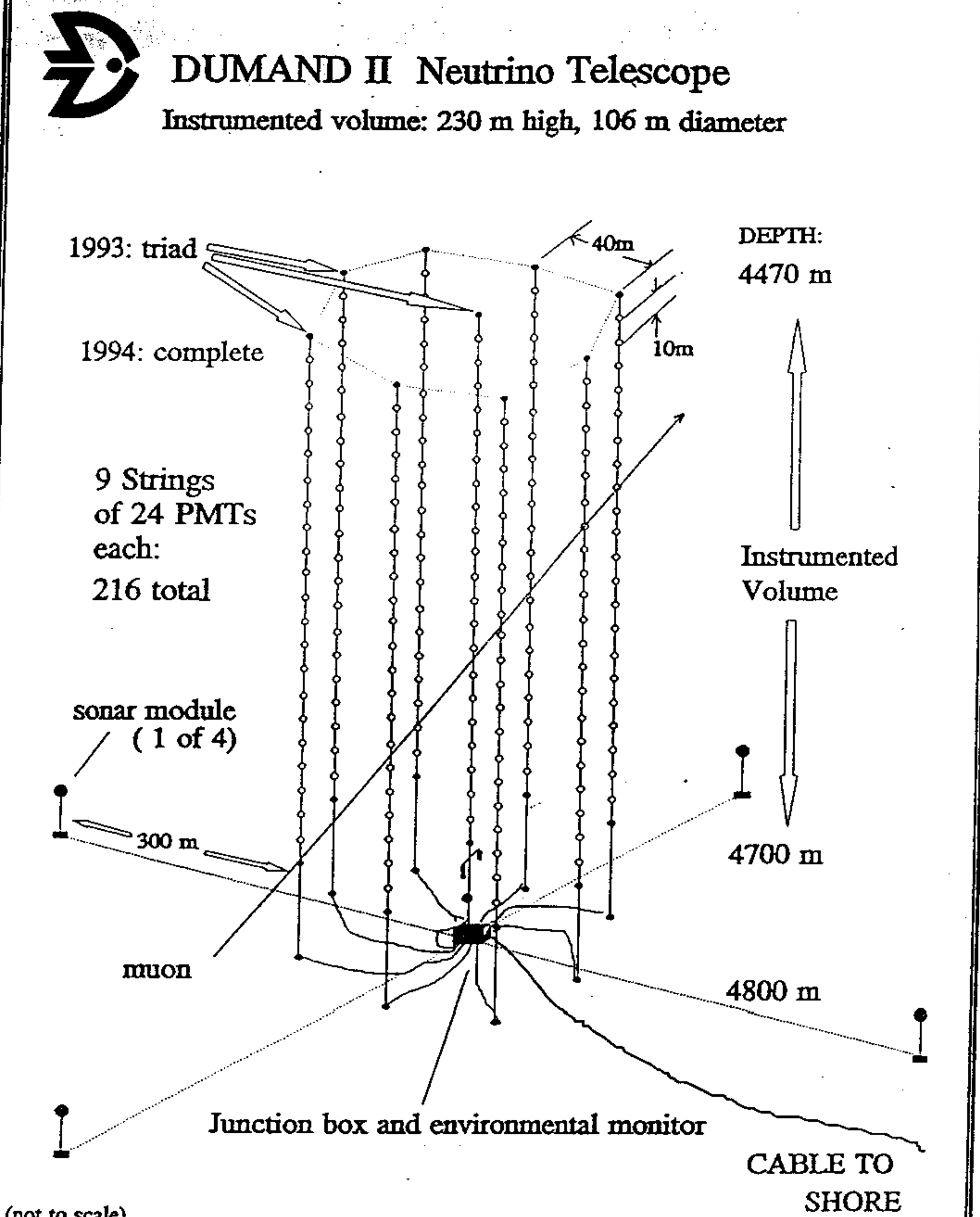
DUMAND II Neutrino Telescope
Instrumented volume: 230 m high, 106 m diameter
1993: triad
1994: complete
40m
10m
DEPTH:
4470 m
9 Strings
of 24 PMTs
each:
216 total
Instrumented
Volume
sonar module
(1 of 4)
300 m
4700 m
muon
4800 m
Junction box and environmental monitor
CABLE TO
SHORE
(not to scale)

Fig. 3