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# Deployment Strategy and Options

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We review the several currently possible scenarios for the initial DUMAND II deployment scheduled for 1993. At this time it is not possible to make final choices because of ambiguities in ship schedules and availability, so we place emphasis on a plan with multiple solutions. Nevertheless, it appears that the best choices for us are: 1) to employ whatever AT&T vessel is on standby in Honolulu for cable repair, deploying only the junction box and cable if the Charlie Brown is here, or include an instrument string in the initial operation should the Brown be replaced by one of the larger and more modern ships in their fleet; and 2) to employ the Laney Chouest, the mother ship for the deep submersible vehicle (DSV) Sea Cliff for both placing strings on the bottom and using Sea Cliff to connect them. Unfortunately for budgetary purposes, both items involve negotiations with the organizations that operate them (AT&T and the USN), and the funding needs remain uncertain.

## I. INTRODUCTION

The DUMAND II array consists of eight bottom tethered instrument strings, 350 m tall, placed around a circle 100 m in diameter, with a ninth string and junction box in the center, and electro-optic cable to 25 km distant shore station, from the 4.76 km deep experiment location West of Keahole Point Hawaii. The equipment is now under construction, and the cable junction box and first three strings are scheduled to be deployed in the Summer of 1993. The junction box carries deep ocean wet-mateable connectors (electrical power and fiber optics). Jumper cables which will be deep ocean installed, connecting to the base of each bottom anchor of the surrounding instrument strings. See the DUMAND II Specifications[1] and System Description[2] for more details. It is desirable, but not mandatory, to install the first string already attached to the junction box at the time of cable laying, so that we begin functioning from the moment the cable is brought to the shore.

The prime choice for initial deployment of one string of instruments, junction box and cable to shore would be an AT&T cable laying vessel of more modern capability than the C/S Charles L. Brown, for example the C/S Long Lines which may indeed be berthed in Honolulu next year. This ship has all the requirements we need for the full scale intial operation, including station keeping and adequate crane capability for launching the instrument string. (Another possibility is the C/S Global Sentinel, a more expensive but new vessel with more than adequate capabilities).

The prime choice for the lowering and placement of strings, and subsequent connection connection to the junction box employing the USN DSV Sea Cliff is the R/V Laney Chouest, mother ship for the Sea Cliff. There are a number of possible alternatives for the string placement, though only a few for the vehicle to carry out the junction box to string connections. If we have the Sea Cliff for connection, it seems a relatively small addition to the task to incorporate the string lowering from the same ship, which is admirably suited to the job.

## II. INITIAL CABLE LAYING WITH OR WITHOUT FIRST STRING

There are five plausible cable-laying ships available to us, as shown in Table I (though, as explained below, other ships would be capable of the cable laying if we could find an appropriate cable engine). All five belong to AT&T Long Lines Division. One is kept on standby in Honolulu at all times in case of cable failure anywhere in the Pacific, and is supported by a consortium of cable companies (a similar arrangement holds for the Atlantic). The standby ship goes to sea several times per year for practice operations, and AT&T considers that DUMAND would make a good practice operation for them, and perhaps would generate some goodwill and good public relations into the bargain. Various verbal offers have been made over the last several years, but we have not been able to reach a firm commitment on which vessel will be available and the daily rates for that vessel, due to the changing situation with AT&T.

The usual vessel in Honolulu in recent years has been the C/S Charles L. 'Charlie' Brown, a 40 year old Italian made vessel. There is little doubt of the ability of the Brown to lay the cable, with junction box attached. In light of the studies completed last month, our favored plan of simultaneously lowering an instrument string already attached to the junction box seems to be possible from the Charlie Brown but not simple enough to make us comfortable with the robustness of the operation. (See the Makai Ocean Engineering, MOE, study of this scenario[3]). The main difficulty has to do with lack of deck space and an adequate crane on the foredeck, which leads to complications in putting the instrument string overboard. The more conservative approach would be to lower only the junction box and shore cable with the Charlie Brown, leaving string placement and connection until later (with different vessels). This approach has been recommended by all reviewers with ocean experience.

However, AT&T is now considering other plans whereby the standby ship might be the much larger Long Lines, the recently built Global Link, the new Global Sentinel, or the not yet finished Global Mariner, at least for a short period (a year or so). These latter three vessels are really transocean cable layers, in contrast to the Brown being a repair ship, and as such they have much more handling equipment, more deck space, and the latter two are both capable of dynamic positioning (DP). The Long Lines has excellent bow thrusters and manual station keeping ability, adequate for our needs, but not true dynamic positioning. The Link, Sentinel and Mariner have all the latest gadgetry, having been designed in light of the recently increased transoceanic fiber optic cable laying activity (as phone companies have realized that fiber optic cables are much less expensive than satellites) and thus they would be nearly ideal for our purposes, except for cost. The costs to us as listed are new and yet tentative figures (and while they seem expensive they are still only a fraction of the total operating costs of these ships). Note that the costs listed are plus fuel (~$1K/day) and whatever modifications are needed for our operations (probably almost nothing for the last three).

Because we have a rather short length of cable by cable-laying standards, where transoceanic runs are measured in many thousands of kilometers, we do not really need such a huge vessel. Our cable weighs 45 tons, which is heavy for a typical research vessel, but not excessive. Our cable could be placed in a pan with splice boxes in place, and payed out over the stern. The problem is obtaining a suitable winch. We need a linear cable engine which will pass the large lumps of splice boxes, and yet handle our relatively small diameter cable (14 mm). We have been as yet unable to locate an appropriate system for lease, since purchase is out of the question. Also, we need to be concerned about a backup for such a winch (which have been known to fail at sea, which could be disasterous for us if we were caught in mid-operation), whereas the AT&T vessels have dual systems which have been run-in over many thousands of kilometers of operation.

The other problem with laying our own cable from an oceanographic vessel, as we had originally planned, is simply the lack of experience on our part. In contrast, the cable-laying operation would be old and standard practice for the AT&T people. It would seem foolish for us to become experts in something we will not often do; nor to which we are likely to make any real improvement in the technology in a short time; nor do we require such. If we carry out the center string placement along with junction box and cable laying, then we are in some new territory for all parties. But even so, the conservative engineering approach favors employment of the professionals, if we can afford them.

On the other hand, AT&T does not have much experience yet with our small size of cable, and the Charlie Brown in particular has not had much small cable experience (this may not be much of a factor since the crews rotate from ship to ship).

Alternative possibities, if a sutiable winch and backup can be found, are the deployment of cable, junction box and first string from either the Independence or Sea Conn, which are described below in the list of oceanographic vessels. It has been the opinion of our consultants, MOE, that the advantages of these ships for the string and junction box deployment outweigh the disadvantages of lack of cable laying experience. In fact both ships have layed cables in operations similar ours, though at more shallow depths, and those were deemed successful by the participants. In this option, these ships could be employed for further string placement, and all operations up to string connection, for which we still need a submersible.

## III. STRING PLACEMENT SHIPS

In contrast to the cable-laying operation, the placement of the strings on the ocean bottom is indeed an operation well suited to a standard oceanographic research vessel, of which there are a dozen examples in the UNOLS fleet. (UNOLS is the US national oceanographic fleet integrated program of funding, which is administered by a central office from NSF, and which is supposedly available to users on a scientific merit basis.)

Particularly important in the placement operation is the ability of the vessel to maneuver with a precision of a few meters in geographical coordinates, in order to lower the string to the spot we desire with a few meters accuracy. (If we have the military GPS then we can know the ship's position to several meters, otherwise using a shore ranging system, such as Mini-Ranger, we can achieve the second-to-second ship position information required). We have considered active thruster packages in the past, which might be used to maneuver the string when near the ocean bottom, but these appear not to offer much improvement in ultimate placement accuracy over a simple passive dangling of the string from the ship, using a computer program to predict motion in delayed response to ship actions at the surface (the 4 km long cable also integrates out all motions of the ship on the minute timescale). So, we need dynamic positioning. DP is not the same thing as being quite easily maneuverable (as for example is the Kaimalino), in that a true DP ship employs navigation information to keep itself on a spot or course, independent of the wind and wave motion (within some limits in sea state of course). Some vessels have good maneuverability, but require human intervention in the ship control. Our inquiries find that this is acceptable, but not desirable.

Table II gives a list of the ships we have been considering. A few words about each are in order.

The Laney Chouest, mother ship for the Sea Cliff, contracted to the US Navy, is a large and capable vessel with almost every kind of navigation and sonar on board. (Being a government vessel it has the full accuracy GPS available). It has a large hanger for the submarine on the after section of the ship, and a specialized launch frame to work over the stern. The Chouest can also carry other systems simultaneously, such as the ATV (Advanced Tethered Vehicle), a deep ocean tethered robot. Moreover, there is a large open area amidships, designed to carry the USN FADOSS (fly away deep ocean salvage system), with large U frame and crane enabling deployment operations to be carried out off the starboard side. The deck in that area is close to the waterline and overhangs the hull by several feet, so no there would not be problems with colliding instruments with the hull (a well known problem with over-the-side operations). We will need to locate an appropriate winch for the string lowering operation, but this is not likely to be a major problem. It thus seems possible that we can do the entire string placement and submarine connection operation with one vessel, though we have not gotten far enough with this plan to assure that there are no insurmountable obstacles. All parties so far contacted approve the notion however. Another great virtue of the Chouest/Sea Cliff operation is that it may well be very inexpensive.

The USN need for such a vessel is infrequent and sporadic, so practice operations are needed to keep the team and equipment in shape. In the past the Sea Cliff has been made available to the scientific community on a fairly informal basis for a total of 60 days per year. This year a new program has come into being, administered by the NURP (National Undersea Research Program) Office, a part of NOAA (National Oceanographic and Atmospheric Administration), which has acquired funding to support the Chouest, Sea Cliff and ATV for a series of scientific dives in the area near Hawaii. We (DUMAND) applied for this time and received 4 dive days scheduled for this Fall, during which we will make practice junction box connections and make detailed site inspections. It is without cost to us.

We have also been informed that the old system for getting time on Sea Cliff is still operable, and indeed we were encouraged by the SubDevGroup personnel to apply to the USN for direct allocation of time for our string placement and connection needs. This would also have been without cost under the old rules, but we are uncertain about the changing situation, as everyone's budget becomes more tight. Still, from what we now know, the ship time may well be free, in which case we need look no further.

The Independence is a highly capable vessel belonging to the US Air Force, intended for booster rocket recovery from launches at Vandenberg in California. It also is lightly used, and available at a bargain rate of $8K/day. Another program in Hawaii (the multi-year Hawaii Ocean Time Series) is also interested in this ship and so we might be able to share the transit costs with them (10 days each way). The ship is well qualified for the string lowering job, with large after deck space, heavy duty cranes and DP, but we need to locate an appropriate winch for string lowering.

The Sea Conn is a USN construction vessel, with cycloidal drive, a moon pool, and lots of electronics. While posessing the cycloidal propulsion means that it can drive nicely in any direction (to which purpose it is flat bottomed and thus a bit rolly), this type of drive has proved unreliable for ocean transit, so the vessel must be towed to Hawaii. This can sometimes be done by catching a ride with a USN tug, but is not easy to schedule nor count upon. The ship also has been employed for cable laying (but has no winch we could use for that purpose, nor for string lowering), and some UH and Makai Ocean Engineering (MOE) personnel have had positive experience on her. The moon pool, which allows string deployment through the center of the vessel would be particularly easy and reliable.

The Melville (Scripps), Thompson (U. Wash.), and Knorr (Woods Hole), are all large (Class II) UNOLS research vessels, with DP. They all have the requisite capabilities for the string placement operation, and would certainly be our choice if UNOLS ships were available to us free of charge and if the Chouest option does not pan out. In fact we have submitted requests for these vessels. None were available on the time scale for our needs (Summer 1992), though the Thompson will pass through our area. It is a fact of life with such ships that the schedules are rather fluid, and we still might be able to have access to one of the three on the time scale we need, though as of now we are not approved for UNOLS time. One can rent them even so, as is commonly done, and much desired by the ship's operators at each institution, to whom such funding is additional income. Generally transit costs are not a problem for the UNOLS vessels, whose schedulers try to work out a route to visit all their customers.

The Vickers (USC) is a smaller, less capable vessel, upon whose schedule we do appear for next year ('92). This vessel does not have DP, but does have good bow thrusters and can probably do the job, but without as much security as would be offered by the others.

The Kaimalino has just left Hawaii for a new home in San Diego, where she is due for some modifications which will make her more maneuverable, but still without DP. Having used her for most of our prototype string operations, we are well acquainted with her capabilities for deploying a string from the deck. The experience of others who have tried to employ her for station keeping has mixed reviews, and our ocean engineering consultants (MOE) do not recommend using her, even in the upgraded configuration. Moreover, we would have to face the transit cost problem, or again, employ opportunities for cost sharing, with attendant schedule problems.

## IV. VEHICLES FOR CONNECTION

There are basically three classes of vehicles for deep ocean work. Tethered robots (remotely operated vehicles, ROVs), free swimming robots, and manned submersibles. The ROVs that are likely available to us all have the problem of concern about entanglement of the tether cable in our array (eg. with the ATV). There are others for whom this should not be a problem (eg. Medea), which use a heavy clump at the base of a stiff cable, and a swimmer to enter the array area. No single ROV of this type is yet available to us for DUMAND. The free swimmers offer much potential for the future (limited as they are by power storage and the few seconds reaction time of acoustic communications), but they are not ready for our use as yet.

This leaves manned submersibles to do the job, which consists of carrying a cable and connector package to the junction box, plugging in the electro-optic connector, stringing out the cable to the base of a string, and then plugging in the string in the same manner as for the junction box. It is a simple, straight forward operation for a human in the laboratory, but as is well known, even simple operations are difficult from such vehicles, so careful design and practice are required.

There are many submarines available around the world for depths to one or two km, but the list goes down to 5 if we ask for those that can operate at DUMAND depth (4.8 km), as indicated in Table III.

Clearly the Sea Cliff is the most readily available to us. The Mir vehicles, which operate as a pair and so come with a backup, are highly regarded in the community (built in Finland). Due to the present situation in Russia, they are readily available to cash paying users, at a bargain rate. If something should happen to the plan to use the Sea Cliff, then the Mirs are probably our best choice, and we have established contact with them. (In fact the Mirs have been in Hawaii on several occassions, and there are ongoing contacts with the local submersible operation, the Hawaii Undersea

Research Laboratory, HURL. Unfortunately HURL has no deep ocean vehicles, yet).

The Shinkai 6500 is a relatively new vessel, and has not ventured this far from Japan as yet, and has a heavy user load in and near Japan. It is possible that we could use her in the future, but given our shifting schedules and the Japanese tendency to rigidly schedule operations long in advance for such ships, we cannot employ her next year.

The Nautile is a French vessel (owned by IFREMER, Institut Francais pour la Recherche Maritime), and mobilization in the Pacific would seem to be inordinately expensive, but we are initiating contacts to explore it as a backup option too.

## V. SHIP TIME AND COST ESTIMATES

All the above taken into account we need to put down some updated figures for budgeting for the ship operations. Let us identify the operations as:

I) Cable and Junction Box with or without first Instrument String

A) Charlie Brown = Cable and Junction Box only.

[2 load, 2 transit, 2 lay, practice at dock]

B) Long Lines, Sentinel, Link, or Mariner = same + String 1

[2 load, 2 transit, 3 lay, 2 practice]

C) Independence or Sea Conn, with cable engine rental

[20 transit, 2 load, 3 lay, 2 practice]

II String Deploy and Connect (2 or 3 Strings)

A) Laney Chouest and Sea Cliff for both

[20 transit, 2 load, 6 place and conn]

B) UNOLS or Equiv Ship + Sea Cliff

[1 load, 2 transit, 3 or 4 place, + 2 transit, 5 conn]

Using the rates shown in Tables I and II, we can now estimate ship rental costs, as in the following matrix, in units of \$K. However, we do not have figures for leasing the Laney Chouest and Sea Cliff, so we assume \$8K/day. These rates are shown in Table IV.

It is probable that the most economically most desirable combination is with the Charlie Brown for cable and junction box, and Laney Chouest doing placement and connection. That would seem to end the story if it were not for the shifting ship opportunities, and the fact that the Charlie Brown may not be berthed in Honolulu next year. Note that we have used here pessimistic estimates of ship costs, as though we would have to pay for the entire ship time. It could well be that the connection and placement from the Chouest is very nearly free, and it even could be (with less likelihood) that the AT&T vessels are less expensive if we are successful in our supplications. A reasonable lower bound might be $200K for ship time, while an upper bound that we might actually be forced to pursue is probably around $500K. Note that we have *not* included the costs or ship preparations and all other ancillary activities associated with deployment, this is ship time costs only.

## VI. SUMMARY AND CONCLUSIONS

We have reviewed the somewhat confusing menu of possibilities for deploying DUMAND II in 1993. We aim at selecting a plan embodying an optimal mix of the desirable characterisitics of reliability, practicability, availability, and economy. There is no doubt that with sufficient cash we could do better than some options considered above. It is particularly a buyers market in these hard times when most organizations are looking for some outside funding. We have previously counted heavily on our access to the UNOLS program, only to find that it seems to be unavailable to us, at least for free (because we are primarily a DOE funded program and NSF budgets are tight). Nor in fact, now that we open our sights a bit, do we find that the UNOLS fleet is so well adapted to our unusual oceanographic needs. Certainly we could employ UNOLS vessels, but there are better ships for our purposes, particularly for the cable-laying operation.

The next few months are going to be an interesting period as we now try to get definite commitments for the ships for our DUMAND II deployment operations next summer!

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## REFERENCES

[1] DUMAND II Specifications, DIR-14-91, HDC.

[2] DUMAND II System Description, DIR-13-91, HDC.

[3] Jose Andreas, MOE, "Study of Deployment of String, Junction Box and Cable from the Charlie Brown", July 1992.

# TABLES

TABLE I. List of cable-laying Ships for DUMAND

| Ship | Year | Length (ft) | DP | Costs ($K/day) |
|---|---|---|---|---|
| Charles L. Brown | 1954 | 300 | N | 25-30 |
| Long lines | 1973 | 511 | $\sim$Y | 35 |
| Global Link | 1991 | 500 | Y | 50 |
| Global Sentinel | 1992 | 500 | Y | 50 |
| Global Mariner | late 1992 | 500 | Y | $\geq$50 |

TABLE II. List of String Placement Ships for DUMAND

| Ship | DP | Avail | Pay Transit | Rate ($K/day) |
|---|---|---|---|---|
| Laney Chouest | /*sim*Y | Y | ? | 8.0 |
| Independence | Y | Y | Y? | 8.0 |
| Sea Conn | Y | Y | Y? | 11.0 |
| Melville | Y | ? | N | 14.0 |
| Knorr | Y | N | N | 14.0 |
| Thompson | Y | ? | N | 14.0 |
| Vickers | /*sim*N | Y | N | 12.0 |
| Kaimalino | N | Y | Y | 5.4 |
| Moana Wave | N | N | N | 12.0 |

TABLE III. List of Submarines useful for DUMAND Connection Operations

| Submarine | Country | Depth (m) | Avail | Transit Costs | Cost ($K/day) |
|---|---|---|---|---|---|
| Sea Cliff | USA | 6096 | Y | N? | 8 |
| Mir (2) | Russia | 6000 | Y | Y | 15(ship)+30(ship) |
| Shinkai 6500 | Japan | 6500 | N? | ? | ? |
| Nautile | France | 6000 | Y? | ? | ? |

TABLE IV. Matrix of Costs for 4 Scenarios of DUMAND II 1992 3 String Deployment

| | II A | II B |
|---|---|---|
| I A | $6 \times (26 \sim 31)$<br>$+29 \times (0 \sim 8)$<br>$= 156 \sim 418$ | $6 \times (26 \sim 31)$<br>$+7 \times (0 \sim 14)$<br>$+27 \times (0 \sim 8$<br>$= 156 \sim 500$ |
| I B | $9 \times (36 \sim 51)$<br>$+29 \times (0 \sim 8)$<br>$= 324 \sim 691$ | $9 \times (36 \sim 51)$<br>$+6 \times (0 \sim 14)$<br>$+27 \times (0 \sim 8)$<br>$= 324 \sim 759$ |
| I C | $(15 \sim 27) \times (8 \sim 11)$<br>$+27 \times (0 \sim 8)$<br>$= 120 \sim 513$ | $(15 \sim 27) \times (8 \sim 11)$<br>$+6 \times (8 \sim 11)$<br>$+27 \times (0 \sim 8)$<br>$= 168 \sim 579$ |