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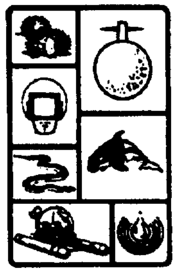

FISCAL YEAR 1972 INDEPENDENT RESEARCH AND INDEPENDENT EXPLORATORY DEVELOPMENT

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NAVAL UNDERSEA RESEARCH AND DEVELOPMENT CENTER, SAN DIEGO, CA. 92132

AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

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Commander

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This report is submitted in response to NAVMATINST 3920.3A of 24 March 1969. It consists of moderately detailed descriptions of nine selected Independent Research and Independent Exploratory Development projects. These descriptions are followed by listings of all NUC IR/IED projects and the journal articles, presentations, and patents that have resulted from them.

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INTRODUCTION

This publication summarizes the Independent Research and Independent Exploratory Development program at the Naval Undersea Center for Fiscal Year 1971. Nine projects were selected for highlighting this year. Of special interest is the continuation of our interest in marine biology evidenced by an examination of an ecological system, a description of venomous and dangerous animals affecting naval operations, an exploitation of porpoise physiology for sonar design, and the use of various human anatomical and sensory characteristics in developing an artificial pinna and a head-coupled television control for CURV. More purely engineering are reports on an NUC hydrodynamic transducer and on the construction of models of submersibles of reinforced concrete.

The imagination of the NUC individual investigator and his free-wheeling approach to the Navy's problems is becoming more evident each year. While this approach is certainly effected in the application of IR/IED funds, it is, sadly, not always true. From existing concepts, like many of these presented here, will come the order-of-magnitude improvement in future Navy operational capability. If conventional active sonar has limitations, perhaps a next-generation sonar will copy the sensory equipment of the porpoise. A small attack submersible of the future might well be equipped with pinna-like sensors and a head-coupled control mechanism, leaving the pilot free for other duties just as a soldier in battle doesn't have to think about locomotion or steering himself. Of more immediate practicability, and tremendously important, is the cataloguing of dangerous and venomous animals so that fighting men will be able to cope with these hitherto unknown dangers.

NUC continues therefore to provide a broad base of scientific knowledge and technology through the application of IR/IED funds. This base must be substantial so that resulting application to engineering design and equipment will be substantial. The scientific and engineering health of this Center will continue to depend upon the wise application of these resources.

NOTE: No IR/IED projects were terminated during this reporting period.

OUTSTANDING INDEPENDENT RESEARCH PROJECTS

PORPOISE SONAR SIMULATION, AN APPROACH TO IMPROVED SMALL-OBJECT-DETECTION SONAR

The Navy's interest in biological sonar, particularly that of various cetacean species, is well documented. The primary impetus for this kind of research has been the possibility of applying the elements of the biological system (such as frequency ranges, levels of energy output, signal characteristics, and critical features of the processing system) to the improvement of present concepts of sonar design. It has been commonly assumed that all cetacean species possess and utilize active sonar systems for navigation and food finding, whereas the use of active echoranging has actually been demonstrated for only a few species. The major problems in obtaining these kinds of quantitative demonstrations have been in positively determining the source of sounds, the pathways for their projection, the characteristics of the projected signal and the comparative characterisitcs of the reflected signals, and in identifying and describing the areas most critical in sound reception and processing. The problem has been further compounded by the nature of the signals the animals use (10- to 100-μsec pulses) and the fact that this type of waveform is essentially foreign to more conventional concepts of sonar design. Even in the few instances demonstrating that a species does use such a system, it has been difficult to determine which characteristics of the target echo the animals are using to make the discrimination. Transmitted signals and their resulting echo waveforms are often distorted by environmental effects (multipath problems). This situation is further complicated by the complex head scanning motions that are associated with the echolocation behavior of most species observed.

In an attempt to obtain answers to these basic question, this laboratory has conducted a series of progressively more sophisticated experiments on dolphin echoranging during the last several years. The first study consisted of conditioning two Atlantic bottlenose porpoises (*Tursiops truncatus*) and one Pacific whitesided porpoise (*Lagenorhynchus obliquidens*) to identify a standard target (a 0.22-cm copper disc) and then asking them to distinguish between that standard target and another target of similar size, shape, and reflectivity. This study demonstrated that both species could distinguish between the standard target and targets very similar in acoustical characteristics to the standard, i.e., ±1 dB in target strength (Fig. 1).

A further sophistication of test targets was attained when a set of precision cylinders was designed and fabricated under contract by the Applied Research Laboratory in Austin, Texas. These targets were 7-in.-long cylinders of a cork neoprene compound (Armstrong Chloroprene, type DC-100), which varied in target strength as a function of diameter in 1.0-dB or 0.5-dB increments. With

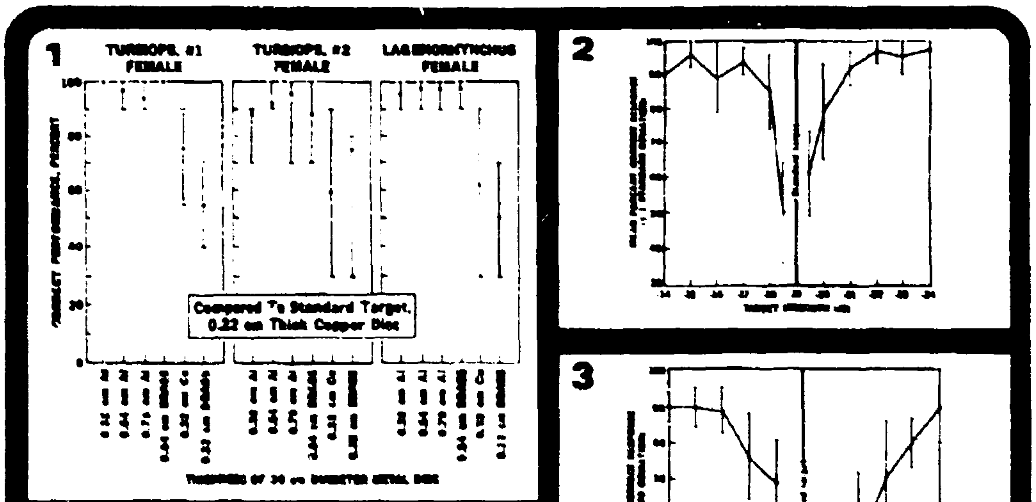
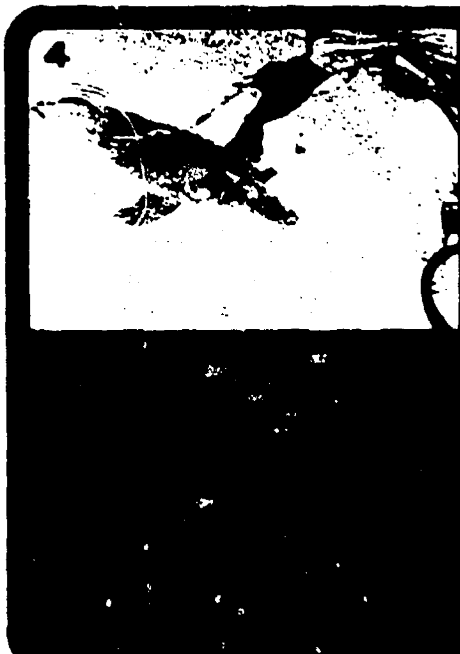


Fig. 1. Results of disc-target discrimination tests with two species of porpoises. Fig. 2. Results of cylinder-target discrimination tests (*Tursiops truncatus*). Fig. 3. Results of cylinder-target discrimination tests (*Inia geoffrensis*).

these targets, another series of tests was conducted with a *T. truncatus* and with an Amazon River dolphin (*Inia geoffrensis*). Each of the animals was blindfolded and asked to distinguish between the standard target and a second target. The difference between the two targets was gradually reduced to determine the subtlety of differences which the animals were capable of detecting. The *Tursiops* exhibited the ability to differentiate consistently between the standard target (−19 dB) and targets varying only 0.5 dB, i.e., −18.5 dB and −19.5 dB (Fig. 2), while the *Inia* was capable of distinguishing reliably between the standard and targets of −17 and −21 dB (Fig. 3).



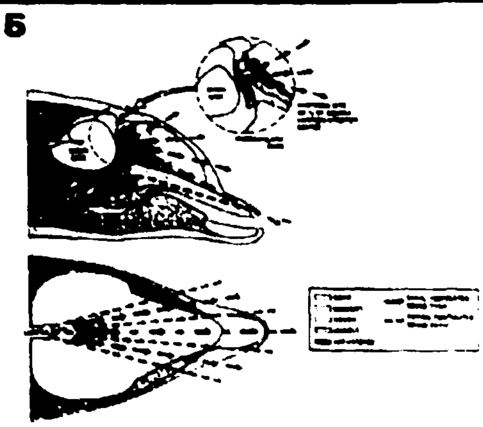
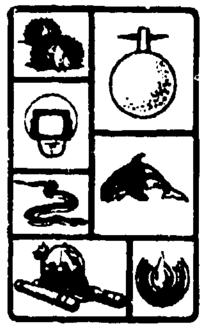


Fig. 4. *Tursiops* (top) and *Inia* wearing test measuring arrays.
Fig. 5. Hypothesized sound transmission routes from head of *Tursiops truncatus*.

More recently, a further sophistication in method of study has been used to minimize the distorting effects attributable to medium and animal movements. By means of attached sensors, recordings were made of signals from three species of Odontocetes (*T. truncatus*, *I. geoffrensis*, and the killer whale, *Orcinus orca*) conditioned to perform the same discrimination task described above (Fig. 4). While performing the discriminations, each of the animals wore a sophisticated series of transducer hydrophone arrays on the areas of the head and rostrum previously identified as being involved in sound production and reception (Fig. 5). A T shaped array of four transducers (BM101 hydrophone elements) was placed by suction cup on the anterior end of the rostrum and used to measure the angular distribution of acoustic signals projected from the anterior surface of the head. A transducer,



placed just behind this array on the rostrum, provided a reference point for all recordings, and additional BM101 hydrophone elements, one placed on each of the eye cups, served to detect the echo at the animal during a target run. Typical waveforms measured at the various locations by means of these instruments are shown in Fig. 6.

At this time an additional project is attempting to measure the maximum distance at which *T. truncatus* can distinguish between the calibrated chloroprene targets. The technique effectively involves placing the two targets on either side of a screen which extends from the wall behind the targets towards the animal's approach path and forces her to select, at a given distance, one of the two targets. The distance at which she will be required to make the decision will be continually increased until the animal is no longer able to make a correct decision at more than a chance level. Future research will concentrate on defining those characteristics of the echo which provide the most important cues in target classification.

The tests conducted during the FY 71 phase of this program resulted in:

- Location of the porpoise sonar sound source, just anterior to the blowhole at a depth of 2 cm
- Definitive description of the emitted field (both near and far)
- Accurate electroacoustic simulation of the porpoise sonar waveforms
- Establishing that Odontocete cetaceans produce a "generic" type of waveform which generally differs from species to species only in source level and peak frequency

A related relationship, which warrants more extensive investigation, has begun to emerge. The peak sound energy of the three species instrumented and examined varies inversely with body size (Fig. 7).

The success of the IR-funded FY 71 program in porpoise sonar simulation is evidenced in the recent sponsorship obtained from Ships Systems Command to continue certain phases of this research.

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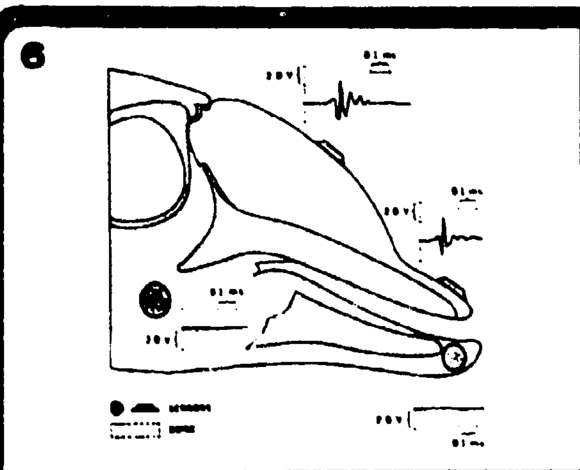

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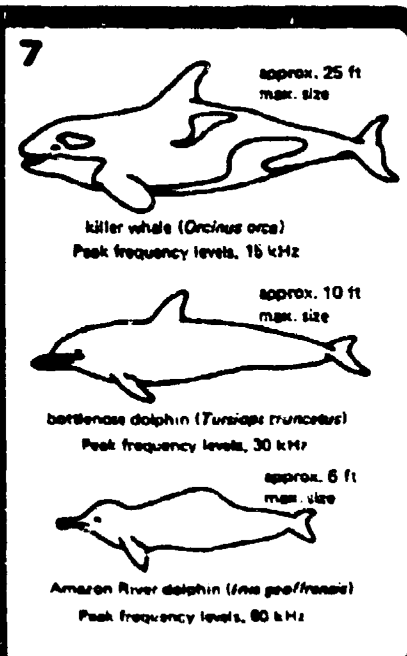

Fig. 6. Typical waveforms measured at various locations on head of *Tursiops truncatus*.
Fig. 7 Relationship between maximum size and relative peak echoranging frequencies in three Odontocete species

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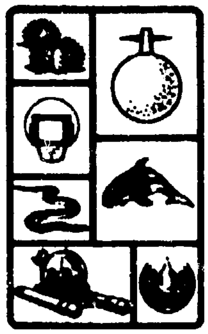


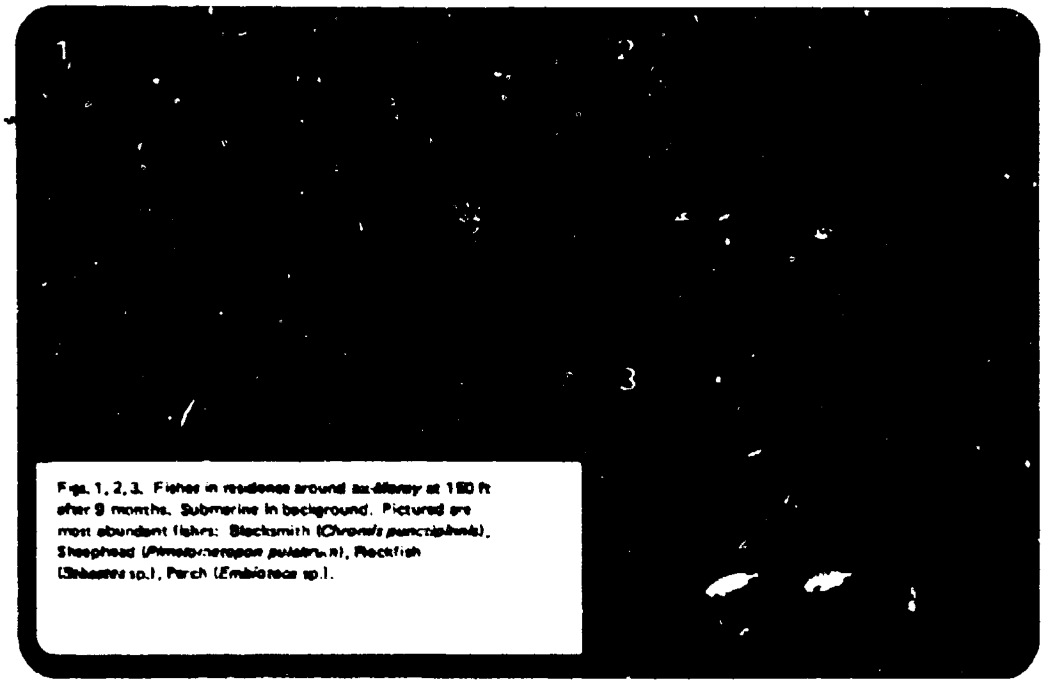
ANIMAL ATTRACTION TO SUNKEN SUBMARINES

During 1969 and 1970 two submarines were sunk off San Clemente Island as part of weapon evaluations. A former fleet sub, the ex-USS *Burrfish*, went down in November 1969 at a depth of 1800 ft off the west coast of the island, while the ex-USS *Moray* went down in June 1970 in 150 ft of water off the east coast of the island. These events provided unique opportunities to study the effects on the bottom ecology of the intrusion of a substantial hulk. A knowledge of the change in ecology may be of value in performing rescue or salvage operations on sunken submarines, evaluating the impact of ordnance dumps in the deep sea, or simply locating sunken ships. Further, with the first Deep Submergence Rescue Vehicle (DSRV) approaching operational status, nuisance animals attaching to or sitting on the areas of escape trunks are also of immediate concern. The objective of this program, then, was to survey the ocean bottom before and after the sinking of the submarines and determine any changes in ecological parameters and patterns in the immediate vicinity.

The approach was to utilize CURV, the Navy's Cable-Controlled Underwater Research Vehicle, to survey the two areas. Its television cameras were monitored on the surface, and its 35-mm color camera on the bottom provided a photographic record for data analysis. Three preliminary surveys were conducted in the area of the ex-*Burrfish* to provide baseline data on the animals present before sinking, but unfortunately circumstances prevented preliminary analysis of the ex-*Moray* site. However the ex-*Moray* was observed and photographed a month after sinking. The first survey after the sinking was made in July 1970 and the second in September of the same year. The next survey came in April 1971. The first post-sinking survey of the ex-*Burrfish* came in December 1969. Surveys were later conducted in January and June 1970 and June 1971. Approximately 1500 photographs were taken of the ex-*Moray* site after its sinking. At the ex-*Burrfish* site, 1500 were taken before the sinking and 3000 after.

It was expected that marine life would be attracted to both submarines, but since the depths involved were considerably greater than previous work with artificial reefs, it was not at all certain what would happen in detail. It is well known that in the marine environment, natural reef habitats support a most impressive diversity and abundance of plant and animal life. Natural reefs include coral reefs, kelp beds, and certain configurations of rock outcrops. Thriving communities exist in these areas because the reefs provide protection, food, and an attachment site.

During the last 10 years, a new type of reef has become increasingly important—the artificial reef. Different organizations throughout the world have been establishing such reefs off their coasts, using everything from automobile wrecks to old streetcars to truck tires to toilet bowls. The results have been quite dramatic. In some cases, schools of fish have moved into the area within 1/2 hour of reef placement, and in others the fish population has increased around the new reef by 300 percent within a period of a few years. It is not only fish that are attracted, however.



Figs. 1, 2, 3. Fishes in residence around ex-Moray at 150 ft after 9 months. Submarine in background. Pictured are most abundant fishes: Blacksmith (*Chromis punctipinnis*), Sheephead (*Pimelometopon pulchrum*), Rockfish (*Sebastes* sp.), Perch (*Embiotoca* sp.).

As a matter of fact, the fish are necessarily supported by the invertebrates and plant life that have also become an integral part of the reef community. The fish might initially come into the areas for the protection, in the form of hiding places, afforded by the reef, but they would not remain there if the food supply were inadequate.

As with most natural reefs, which are shallower than 100 ft, most of the work done with artificial reefs has been in 100 ft of water or less. These depth limitations are imposed by the attached algae, which thrive in shallow water, and the ease in working with SCUBA in shallow water for field analysis of reef effectiveness. Having one artificial reef in the form of a submarine at 150 ft and another at 1500 ft will provide valuable information for ascertaining the significance of artificial reefs at dif ferent depths and the processes that are involved in establishing new communities at those depths.

In the case of the ex-*Moray* at 150 ft, many fish had apparently taken up at least semipermanent residence less than 1 month after the submarine was sunk. As mentioned, no surveys were conducted before the sinking, but the greater number of fish around the submarine, as opposed to nearby areas at the same depth, is quite apparent. As the CURV moved along the bottom and approached the ex-*Moray*, it started to photograph from distances of about 100 ft, and few fish were observed. But, as soon as the sub was visible at a distance of approximately 15 ft, fish could be seen in the hundreds. Since the fish are the most mobile animals in the area, one would expect them to be the first inhabitants of the new reef. Surveys 3 months and 9 months after sinking revealed even more fish, with the last survey showing fish in almost every photo.

The ex-*Moray* sits on a sandy bottom. There are a few rock outcrops, and a hydroid-bryozoan community carpets the bottom in surrounding areas. Numerous mussels were also observed in certain patches on the bottom, but it is believed that this population is extraneous, since *Mytilus* sp. is usually found at a much shallower depth. It is believed that clumps of these mussels were knocked off from higher zones and came cascading down or that perhaps they were knocked off the hull of the submarine during sinking. Many empty mussel shells were observed. These animals were killed by the explosion before the sinking or fell victim to predation by starfish. There was photographic evidence that starfish, both *Patiria miniata* and *Pycnopodia helianthoides*, were actively feeding on these mussels. One picture shows a starfish feeding on mussels still attached to the bottom of the submarine.

Because of the fouling organisms that were attached to the submarine before sinking, it is difficult to tell which animals, if any, have started to colonize the hulk itself. There is little evidence that animals attached to the sub while on the bottom and nothing very indicative of attraction on the part of the more mobile invertebrates expected to aggregate on and around the submarine. Most in evidence were the starfish feeding on the mussels, but these were not attracted by the sub itself. However, most of the initial colonizers of the reef are relatively small in size and would be very difficult to see in a photograph. The fish most common in the area of the submarine and apparently using it for shelter are the blacksmith (*Chromis punctipinnis*), sheephead (*Pimelometopon pulchrum*), rockfish (*Sebastes* sp.), and perch (*Embiotoca* sp). Since this particular artificial reef has been in operation for less than 1 year, there may not have been enough time for the initial colonizers to establish themselves. If they do, one could predict the influx of the larger mobile invertebrates and the establishment of a thriving community with its own food web

In the case of the ex-*Burrfish*, three surveys were conducted before the submarine was sunk, and over 1500 photos were available for analysis of the bottom in the area where the sub was scheduled to go down. These revealed a bottom of soft sand and mud with a gentle slope and very few, isolated rock outcrops. The epibenthic macrofaunal community was dominated by echinoderms. In order of decreasing abundance were found heart urchins, probably *Brisaster* sp. and *Brissopsis* sp., regular urchins (*Allocentrotus fragilis*); unidentified sea anemones; sea cucumbers, brittle stars, glass sponges, fish, and crabs. It must be remembered that although the echinoderms made up over 90 percent of the animals living on the bottom, they actually constitute only 4 or 5 percent of the total biomass. The reason for this is the enormous numbers of animals, like polychaete worms, living in the sediment itself and not visible to the camera. This analysis by necessity only includes those animals normally found on the bottom surface.

Although the burrowing heart urchins were the most abundant animal in the preliminary surveys, the particular site where the submarine actually touched bottom at 1500 ft was dominated by the pink sea urchin (*Allocentrotus fragilis*). Further, this site was much more sparsely populated than those previously surveyed. Therefore,

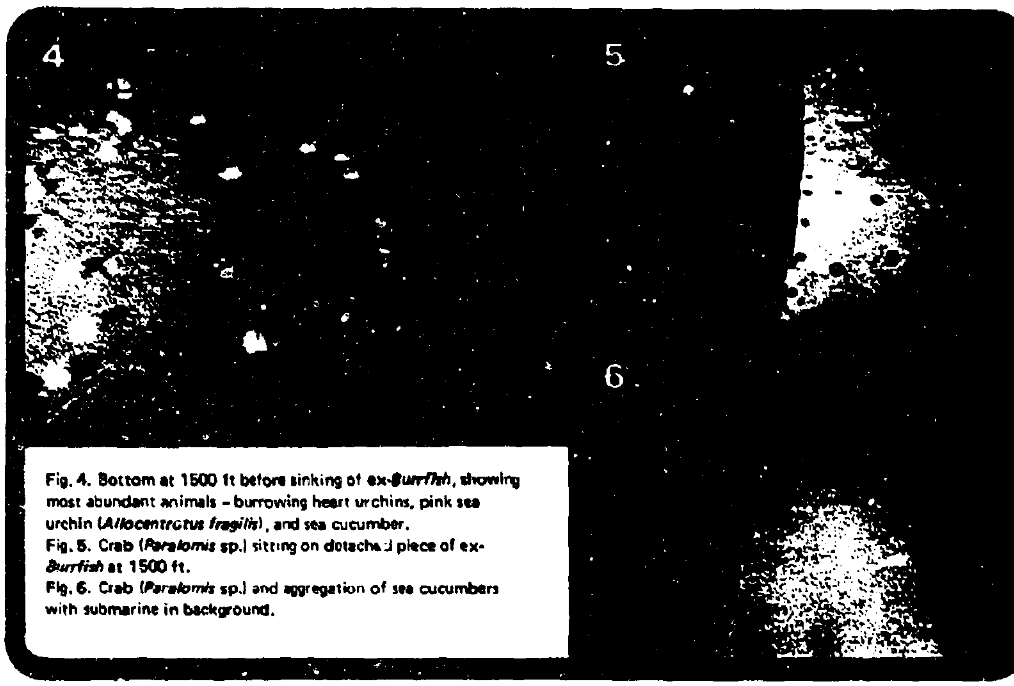


Fig. 4. Bottom at 1500 ft before sinking of ex-*Burrfish*, showing most abundant animals – burrowing heart urchins, pink sea urchin (*Allocentrotus fragilis*), and sea cucumber.
Fig. 5. Crab (*Paralomis* sp.) sitting on detached piece of ex-*Burrfish* at 1500 ft.
Fig. 6. Crab (*Paralomis* sp.) and aggregation of sea cucumbers with submarine in background.

it should be easier to determine any influx of marine life. Because of the depth involved, one would not expect the same type of reef to be established as around the ex-*Moray*. In the first place, there are not as many fish on the bottom at 1500 ft around San Clemente as there are at 150 ft, and they do not exhibit the same schooling behavior. Secondly, there are no plants at 1500 ft, so one would not expect to find algae attaching to the hull of the submarine. For that matter, there are few fouling organisms attaching at that depth. Thus a colonizing community of attached plants and animals would not occur here.

To date, 20 months after the ex-*Burrfish* was put down in 1500 ft of water, the two animals apparently attracted to the submarine are Lithodid crabs (*Paralomis* sp.)

and Aspidochirote sea cucumbers. During the preliminary surveys, only one or two of these crabs were seen, but over six have been photographed in the immediate vicinity of the submarine, in most cases standing on or next to debris from the sub. The sea cucumbers were quite numerous in preliminary surveys but not aggregated in the same gregarious way in which they are now found within 15 ft of the ex-*Burrfish*. The same is true for the few fish that were observed. They could be found in some cases sitting together in groups of two or three on and around parts of the submarine. What seems somewhat surprising is that very few animals were on the submarine itself. In previous experience with the pink sea urchin (*Allocentrotus fragilis*) at the proposed SEALAB III site at 600 ft, it aggregated on bottom equipment. Thus it was expected to crawl all over the sub in great numbers. This apparent anomaly may be explained by the large size of the submarine, which would place the urchins some distance above the natural sandy bottom. On the other hand, it may just be too soon to tell.

In summary, influx of marine life in the area of the ex-*Moray* at 150 ft has been much more rapid and dramatic than in the area of the ex-*Burrfish* at 1500 ft. This is due in part to the mobility of the fishes in the area and the number of schooling fishes. From the photographs, it does not appear that any of the larger mobile invertebrates have come into the area, except the starfish that have moved in to feed on the mussels. At the ex-*Burrfish* site, however, movements of fish have not been very pronounced, although there are fish closer together around the submarine than in other areas. Most dramatic in the area of the ex-*Burrfish* are the crabs seeking protection around the submarine and the comparatively large aggregations of sea cucumbers.

These studies are just beginning. Baseline data are being gathered. It will probably take years for all the ecological patterns to be completed and the available niches around the submarines to be filled. It does appear that colonization of the ex-*Moray* at 150 ft will occur much more rapidly than colonization of the ex-*Burrfish* at 1500 ft. Ecological processes are generally more depressed at greater depths, and it will take longer for all the patterns to emerge and establish the reef community food chain. Once the information is in, however, we can better evaluate the ecological impact of deep dumping sites used for things like obsolete ordnance and weapons. It will also aid in the selection of potential dump sites, should they be required, or suggest other techniques for disposal. Study of the colonization of the hulks will yield valuable data concerning rescue and salvage operations, such as potential interference from attached animals or semipermanent residents. Further, we will gain more insight regarding nuisance marine animals that might congregate in future undersea habitats.

VENOMOUS AND DANGEROUS ANIMALS AFFECTING NAVAL OPERATIONS

INTRODUCTION

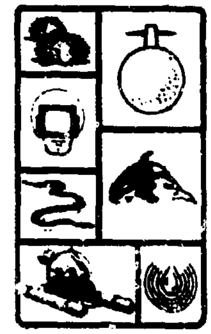
This Independent Research program was funded as a discrete research project for the first time on 16 August 1970. Funding was terminated 30 June 1971. During the 10½-month tenure of the project, research into several important aspects of the basic problem—encounters with potentially harmful or lethal animals by Naval personnel (including UDT, SEAL, and Marine Corps troops)—was undertaken with several goals in mind.

The first, short-term goal was production of a Handbook of Dangerous Animals based on a solid research format (described below), and designed for use by the personnel most concerned—the troops in the field. During extensive interviews with potential users, it became apparent that such a source of information concerning potentially dangerous animals frequently or occasionally encountered was not available to these personnel, that such a source of information would be enthusiastically welcomed, and that about 80 percent of those with one or more tours overseas had experienced one to several encounters with potentially dangerous animals, a few under rather harrowing circumstances.

It was learned that such a source of information would have a distinctly beneficial psychological effect on the attitudes of the men toward the potentially dangerous animals they are likely to encounter.

A related, longer term goal involved production of subsequent editions of the Handbook to include additional animals and geographical areas found to be of importance, and a broadening of orientation to include Army and Air Force interests as well. To the best of our knowledge, neither organization is conducting a similar program. Thus we hoped eventually to produce an all-service handbook of relevance and value to operational personnel of all branches in the field. No such product exists today, although at least two good handbooks and one recent comprehensive treatise on dangerous marine animals have substantial value to persons with access to them and a suitable educational background. The goal was to produce a scientifically accurate, well-illustrated, plain-language manual that would cover important biological, behavioral, and medical aspects of the commoner dangerous animals encountered, primarily in S. E. Asia.

A final, concurrent aspect of the Dangerous Animals Program, no less important than the others, involved establishment of laboratory and research studies aimed at



strengthening weak, but important, areas in our knowledge of potentially dangerous animals that came to light as the various sections of the Handbook were compiled. Further, this research was intended to investigate relevant medical aspects, such as potentially useful detoxifying agents for snake venoms.

Three such studies have already produced substantial preliminary results. One, a study on behavior of sea snakes when seized or otherwise restrained, was recently published,* while ancillary observations of sea snake responses to nearby SCUBA divers in the water have been presented in detail in another study on relevant aspects of sea snake biology.† The third study, on snake venoms, is aimed at defining the major toxic factors common to the venoms of the most frequently encountered snakes, and producing an antitoxin that will be efficacious against all of these species.

The goal of the third study is to produce an antidote for snake bite envenomation that can be belt-carried by field personnel and requires no refrigeration. This is a difficult and considerably longer term goal, requiring facilities not at present available at NUC. Toward the end of the 10-½-month funding period, preliminary studies on sea snake venom, the most potent of all snake venoms, were nearing completion and resulted in three manuscripts now in final stages of preparation.

Following is a detailed description of the two main aspects of this program:

THE HANDBOOK

In 1969, prior to preparation of the IR program summary proposal, interviews were conducted and briefings were held for the three UDT teams and certain officers of Special Warfare Group, Pacific. Subsequently, there have been meetings with Marine Corps officers and with personnel of the Army Medical Corps and the Navy Bureau of Medicine. Substantial enthusiasm was the characteristic response from every quarter, and the program has benefitted from suggestions and descriptions supplied by the men themselves of actual encounters with potentially dangerous animals.

As predicted, the true seriousness of the problem of encounters with potentially lethal animals is not that heavy casualties are sustained, but the psychological

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*G. V. Pickwell, "Knotting and coiling behavior in the pelagic sea snake, *Pelamis platurus* (L.)," *Copeia*, Vol. 2, 1971, pp. 348-350.

†G. V. Pickwell, "Toward a biology of sea snakes," *Fauna, The Zoological Magazine*, No. 4, 1971 (in press).

effects produce responses on the part of field personnel often or occasionally detrimental to their missions. It was felt by most who were interviewed that these fears would be partially offset by information obtained from the proposed Handbook, and ultimately relieved to a great extent if and when an antitoxin could be developed to be carried and used by the troops in the field. Field personnel have been bitten and killed by venomous snakes, however, and there are what appear to be reliable reports of missions that were aborted because large crocodiles were known to be present.

The first edition of the Handbook will contain sections on individual groups of animals, each section written by one or more authorities on the biology of that particular group. The sections will contain descriptions of individual species, geographical distribution, habitat descriptions, and wherever possible, photographs in color of the animal in question. Additional information will include comments on the relative potency of the venom (in the case of snakes), and accounts of what suitable medical treatment is available, what methods are best to follow to counter possible attack by the animal in question, and what to do if bitten or seized (as in the case of crocodiles).

Should funding continue, it is planned to update existing sections and add new ones as the need arises and new information becomes available. Updating of individual sections and entries within sections will be facilitated by producing the Handbook in loose-leaf form.

A medical section is planned that will provide relevant information, not available elsewhere, of importance to field medical personnel. Examples from the first edition are laboratory studies of the effectiveness of various commercially available antivenins in the treatment of snake bite from several venomous species common in S. E. Asia. These works are supplied by the U. S. Army in a very welcome first effort at collaboration on this project.

It is planned to have the manuscript for the first edition of the Handbook completed about October 1971. An outline of the first edition of the Handbook follows:

NUC HANDBOOK OF DANGEROUS ANIMALS FOR FIELD PERSONNEL

(Produced in Collaboration with Units of the U.S. Army Medical Corps)

Contents

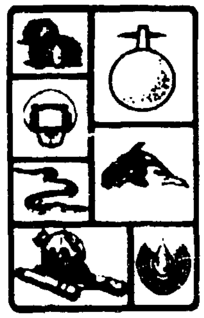

Fig. 1. World-wide distribution of the sea snakes (family Hydrophiidae). Area covered by vertical, horizontal, or cross-hatched bars indicates region occupied by representatives of the 50 species within the family. Areas in red indicate distribution of the single pelagic species, *Pelamis platurus*. Cold ocean currents limiting the spread of this species are shown in dark blue; warm ocean currents responsible for transporting this species farther than other sea snakes are shown in yellow. Note absence of sea snakes in the Atlantic and Mediterranean.

D. Crocodiles of S. E. Asia. by W. E. Evans and H. W. Campbell
   Where Found. General Habits. Aggressiveness and Behavior toward Man.
   What to Do If Seized by a Crocodile.
   Species Accounts.

F. Medical Aspects.
   1. Evaluation of Pit Viper Antivenin against *A. Rhodostoma* Venom. by J. A. Vick and M. Grenan.
   2. Evaluation of Antivenoms (Haffkine Institute, Bombay, India and Commonwealth Serum Laboratories, Melbourne, Australia) against *Naja naja* and *Bungarus caeruleus* Venoms. by J. A. Vick and M. Grenan.

Section B on sea snakes will include broad-scale distributional maps (Fig. 1) as well as smaller regional maps. Examples of the type of illustration intended to portray major sea snake types are shown in Figs. 2 and 3.

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Individual species write-ups will be in the format shown below, and illustrations will depict common color and pattern variants of the snake; distribution maps will indicate occurrence of the given species within S.E. Asia.

Example of a species description.

COMMON COBRA *Naja naja* (Linnaeus)

A large (up to 6 feet) brown or black snake with no markings, or with scattered white specks. There is usually a design on the neck which is spread as a "hood" when the snake is alarmed.

Color of back and belly is olive drab, brown, or black. Chin usually white, followed by a dark bar, with a white bar on the throat.

The alternating bars on the throat are good identification marks. Some of the rat snakes may resemble the cobra, but they do not have the design on the hood, or the throat bars.

Common virtually anywhere except dense rain forests. This snake has earned the nickname "spitting cobra" for its habit of spitting venom, which it does quite accurately for up to 4 or 5 ft. (There are several races of cobras and not all seem to have this habit.) Venom in the victim's eyes can be painful and could cause damage if not flushed out quickly. The cobra's large size, abundance, and quick temper make it one of the most dangerous snakes in the area.

Antivenin is available from Queen Saovabha Institute, Bangkok, Haffkine Institute, Bombay, and Commonwealth Serum Lab., Parkville, Victoria, Australia.

"Ular tedong sendok"–Malay
"Ular bedul"–Malay
"Ngu hau"–Thai

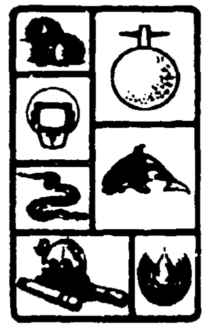
LABORATORY AND FIELD RESEARCH

In addition to the behavioral studies mentioned above, further field observations on sea snakes were carried out during FY 71 (March) on board NUC's R/V *Cape* during the cruise PELACAN I to the Pacific coast of south-central Mexico. It was found that the high turbidity of the water from upwelling and increased productivity at this time of year rendered the sea snakes invisible to SCUBA divers beyond a distance of about 10 ft. Further behavioral tests at that time were cancelled due to increased risks arising from the adverse visibility, which also prevented effective underwater photography.

It was learned, however, that the sea snakes in this area, a species called the yellow-bellied sea snake (*Pelamis platurus*), tended to wash up on the beaches, where they were quite helpless though still alive and vigorous. We were unable to discover the behavioral mechanism contributing to this stranding behavior, but believe that the snakes, even though helpless on land, constitute a very real danger to anyone who might accidentally step on one while walking along the beach (Figs. 4a, b).

During PELACAN I we succeeded, for the first time anywhere, in fractionating whole, freshly obtained sea snake venom by gel filtration on a column chromatograph designed for use aboard ship. The venom fractions obtained aboard ship proved chemically identical to fractions from whole venom obtained in the laboratory at NUC.

Preliminary studies on the toxicity and pharmacology of the crude whole venom and the venom fractions conducted in collaboration with the U. S. Army at Walter



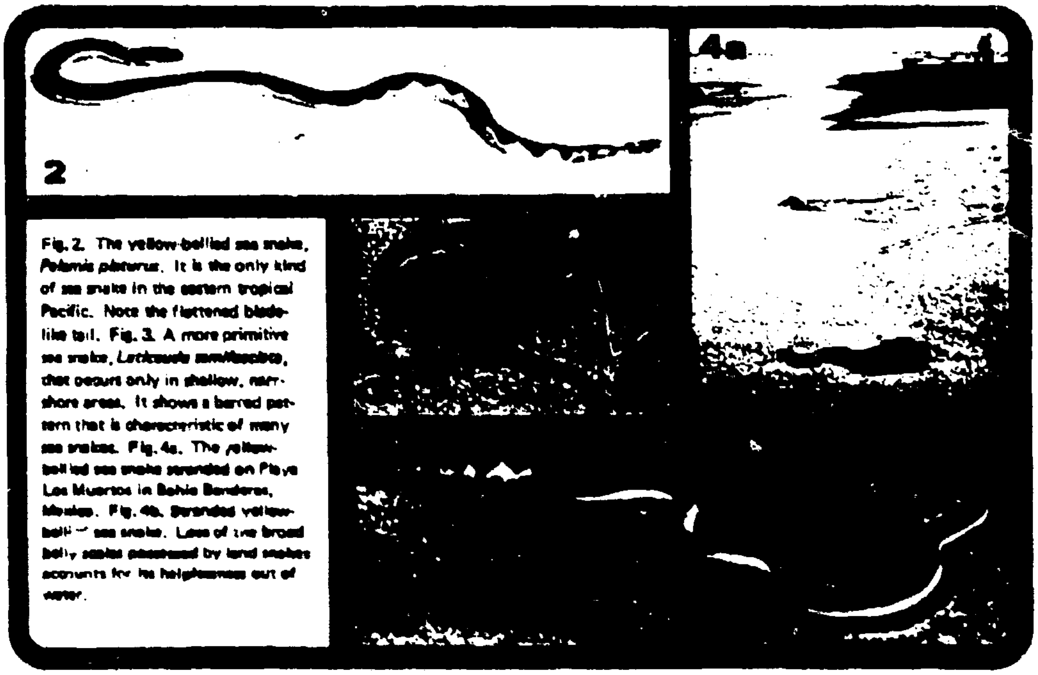


Fig. 2. The yellow-bellied sea snake, *Pelamis platurus*. It is the only kind of sea snake in the eastern tropical Pacific. Note the flattened blade-like tail. Fig. 3. A more primitive sea snake, *Laticauda semifasciata*, that occurs only in shallow, near-shore areas. It shows a barred pattern that is characteristic of many sea snakes. Fig. 4a. The yellow-bellied sea snake stranded on Playa Los Muertos in Bahia Banderas, Mexico. Fig. 4b. Stranded yellow-bellied sea snake. Loss of the broad belly scales possessed by land snakes accounts for its helplessness out of water.

Reed Army Institute of Research in Washington, D. C., indicate that the venom of this sea snake (*P. platurus*) is extremely potent, with an LD 50 for mice, dogs, and monkeys of 0.09 to 0.12 mg/kg, i.e., among the most lethal snake venoms known, and several times as toxic as the venom of the common Asian cobra. Preliminary tests on mongrel dogs and on a primate indicated the primary cause of death to be respiratory arrest at all lethal levels.

During PELACAN I, a method was devised of obtaining venom from this snake, a species that had not previously been successfully milked. The method employed three operators, one restraining and manipulating the snake, the other two each obtaining venom from the fangs on opposite sides by means of capillary tubes (Fig. 5).

Fig. 5. Milking the venom from the yellow-bellied sea snake.

Venom yields indicated that a healthy adult yellow-bellied sea snake possesses venom equivalent to one-half to greater than one lethal dose for an average human adult male. The venom yields, milking procedure, and preliminary results of toxicity and pharmacology studies will be described in forthcoming journal articles.

OUTSTANDING INDEPENDENT EXPLORATORY DEVELOPMENT PROJECTS

REINFORCED CONCRETE SUBMERSIBLES

Surface ships of the Navy, regardless of their top speed or their maneuverability, are easy targets for present-day modern missiles. These ships are highly vulnerable to detection and destruction in an all-out attack. It would appear that the only recourse would be for the major part of our Navy to go underwater. In the undersea environment, detection is very difficult. Sonar detection is only marginally successful in the vast reaches of the ocean.

There is a need, thus, to determine what portion of naval operations could be accomplished underwater and at what expense. Entailed in these considerations is a departure from traditional surface ship concepts, both in shapes and fabrication techniques.

NUC has made several studies of a variety of hull configurations and uses for limited-depth submersibles. These studies have mainly concentrated on the use of reinforced concrete for the basic hull material. Concrete can be formed by repetitive casting techniques, wherein reuse of the form or mold reduces construction costs.

The NUC studies indicate that very large concrete hulls can be constructed for limited-depth use. With moderate working stresses for the concrete, the hulls can be constructed to withstand pressure and buckling forces. This can generally be accomplished without the use of ring stiffeners.

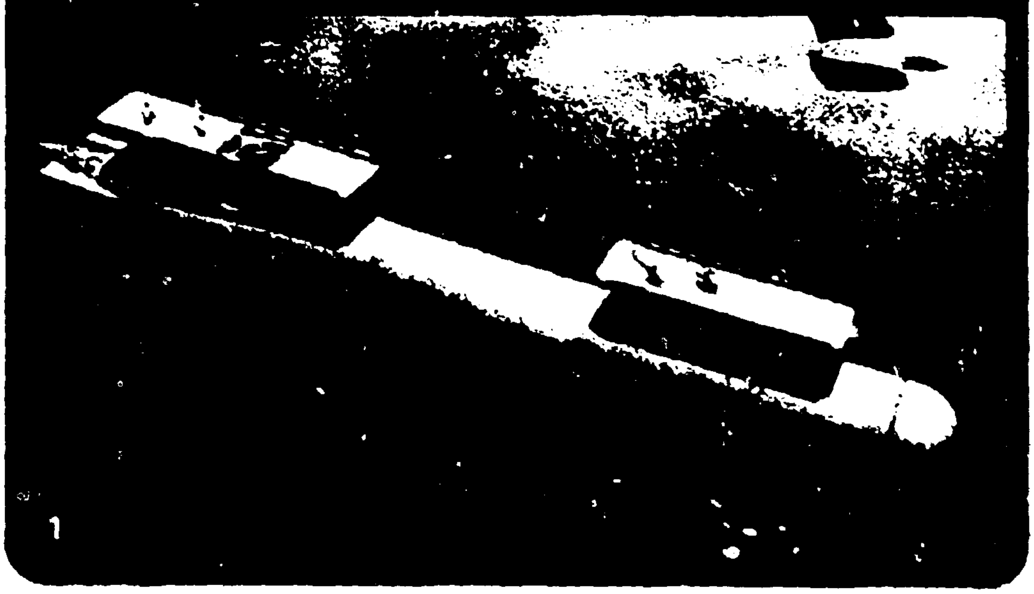
A variety of missions have been considered for reinforced concrete submersibles. Some of these are:

● UNDERWATER HELICOPTER CARRIER: A scale model of an Underwater Helicopter Carrier is shown in Fig. 1. In this instance the aircraft carrier has two large elevated hatch openings for use in the handling of helicopters in and out of the submarine. Each of the two openings will have an elevator and an adjacent flight deck. The elevated hatch opening serves as a reduced water plane area to reduce the wave response of the submarine during launch and recovery of the helicopters.

● UNDERWATER AIRCRAFT CARRIER: Figure 2 shows a submarine similar to that in Fig. 1, except that the elevated deck is continuous from the forward to the aft hatch opening. This configuration could possibly be used for the launching of conventional or VTOL aircraft. The flight deck indicated in the drawing is supported by a series of streamlined vertical struts. This configuration maintains a minimum water-plane area effect to reduce wave response of the landing platform. The height of the flight deck above the submarine pressure hull can be designed for use in moderate to reasonably heavy seas.

● MOBILE UNDERWATER DRY DOCK: Figure 3 shows a large, undersea reinforced concrete dry dock. The dry dock consists of a main center dry dock hull and two adjacent water ballast transfer hulls. The forward end of the center hull has a large watertight door. This door is constructed with a built-in buoyant chamber to neutralize the weight effects and simplify the opening and closing of the door. The

Fig. 1. Scale model of underwater helicopter carrier.



entire structure could be self-powered or towed to location. It could rest on the bottom or could be anchored beneath the surface in a taut moor.

● UNDERWATER CARGO VESSEL These construction principles have also been utilized in the preliminary design of a large reinforced concrete cargo vessel. Its hatch openings are large enough to handle containerized cargo. A vessel of this type could be either self-powered or towed. The cargo hatches of this vessel could be constructed to have an elevated trunk similar to the one shown in Fig. 1. The cargo submarine would then be less responsive to the waves when ballasted low in the water and may then be compatible for use with a large stable ocean platform.

● DECOY: Reinforced concrete submersibles have also been considered for use as decoys. The covert nature of ballistic missile submarine fleet operations could be enhanced by a fleet of decoy submarines made to look and sound like ballistic missile submarines. Since there need be no missiles, auxiliary equipment, or torpedoes, and because a much smaller crew would be required, the greater weight of a concrete hull would not be a disadvantage. The internal equipment would be kept to a minimum in these decoy submarines, and the greater portion of the overall cost would be hull cost. With repetitive casting techniques, a large number of concrete submarine hulls could be built for about one-fourth the cost of steel hulls.

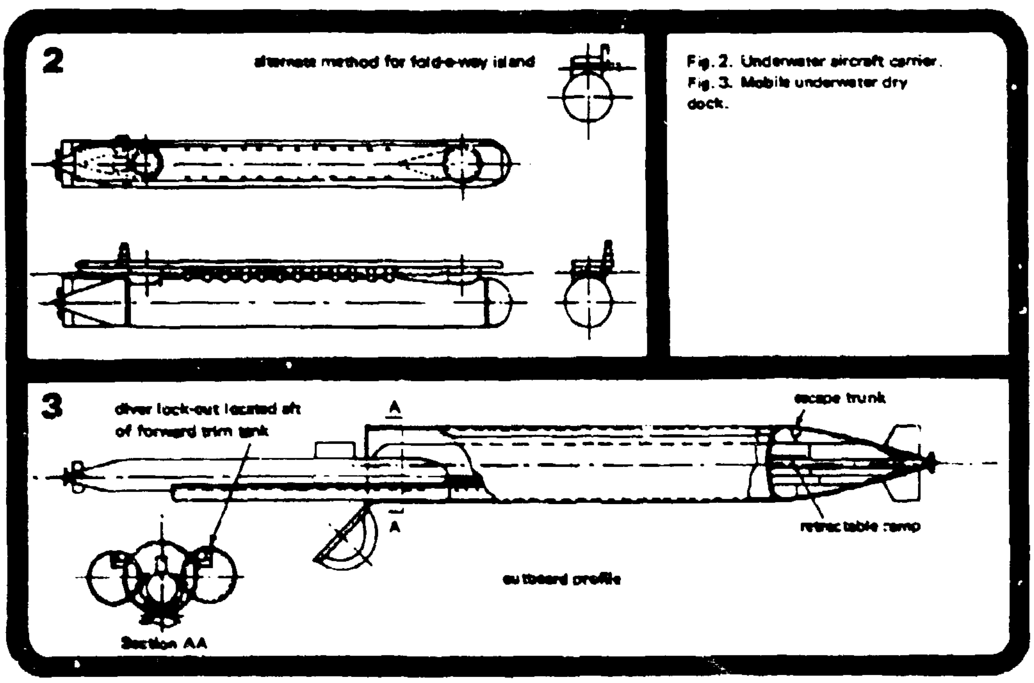


Fig. 2. Underwater aircraft carrier.
Fig. 3. Mobile underwater dry dock.

Further studies are planned for the scale model pictured in Fig. 1. These studies will include dynamic response in the launch and retrieval mode. Studies of coupling or mating with the large model stable platform array are also anticipated. Underwater tow studies of the model submarine should also be conducted to establish drag and towing characteristics. It is anticipated that the submersible could be towed or self-propelled, depending on the required use.

ADAPTATION OF HEAD-COUPLED TV TO CURV

Head-coupled television is one of several names given to remotely controlled television systems in which the attitude of the camera is controlled by the attitude of the operator's head. In these systems the field-of-view as seen by the television camera is always presented directly before the operator's eyes, regardless of any head motions. Typically, this is done by mounting the television monitor or cathode ray tube on a helmet worn by the operator. Electromechanical feedback devices are generally used to synchronize the motions of the camera with those of the operator's helmet. As a result, the operator's hands are freed for tasks other than panning and tilting the camera; but more importantly he is presented with visual and spatial orientation information that gives him the sense of actual presence at the camera location. As the operator moves his head from left to right and up and down, he gains an instinctive awareness of the location of objects in the vicinity of the camera.

This device has important applications in underwater operations. In the case of the Navy's Cable-Controlled Underwater Research Vehicle (CURV), the camera and a mechanical "arm" or manipulator for recovering objects are located below the surface and monitored above. Thus, if an object to be recovered lies below and to the left of the camera and the manipulator is above and to the right, the operator can determine this fact with a single sweep of his head and immediately begin to move the manipulator in the proper direction. In contrast, with a conventional fixed monitor and hand-controlled pan and tilt, by the time the operator located the object, then relocated the manipulator, he would have lost the sense of direction of the object.

Adapting this concept to the CURV III was accomplished with a minimum of modification to the existing vehicle, but resulted in the development of a simple first-order unilateral electrohydraulic position feedback system. For this system a helmet-mounted television display was purchased from the Naval Weapons Center at China Lake, California. A modified version of the NWC helmet linkage, a three-dimensional parallelogram, was fabricated to allow freedom of head translation. Two potentiometers are mounted between the linkage and the helmet to sense head yaw and pitch. This information is transmitted to the vehicle, where it is compared with similar information from oil-filled pressure-compensated potentiometers on the camera pan and tilt. Whenever the position error between helmet and camera exceeds a small limit (about 2 degrees) a relay is actuated, which in turn activates the CURV hydraulic system in such a way as to eliminate the error.

The system was checked out in the laboratory and then mounted on the CURV III vehicle in August of 1970. A malfunction in the system was apparent but was not located before the vehicle was lost off the coast of Washington. The malfunction was later found to be due to an error in the installation drawings and was easily corrected. The system was again delivered to the CURV III operating crew in June of 1971, after a new vehicle had been completed and checked out. Rigid sched-

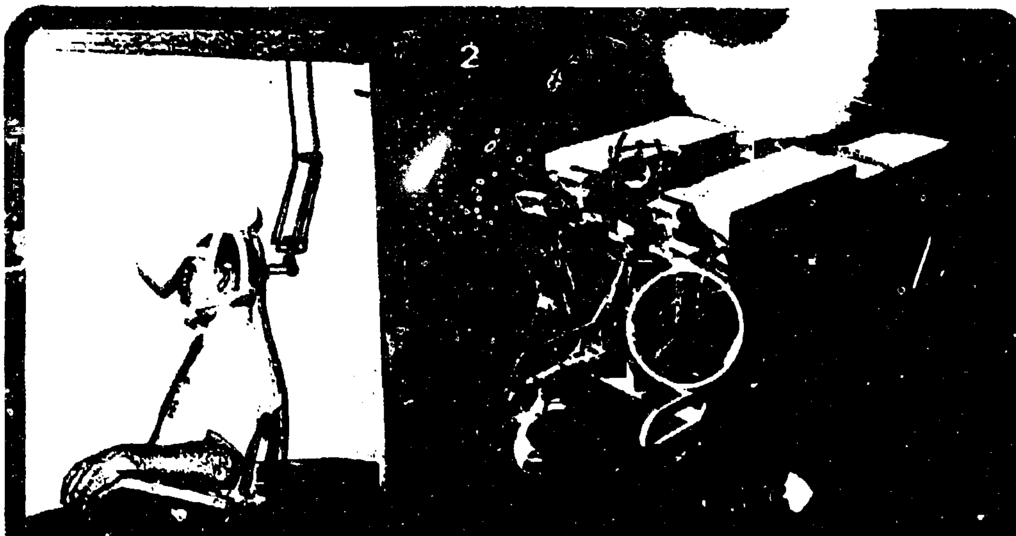


Fig. 1. Head-mounted display and head-motion sensors. Fig. 2. CURV III. Circle encloses head-coupled television pan and tilt gimbal.

uling has delayed installation of the system. The HCTV should be installed and operating by early fall, 1971.

ARTIFICIAL PINNA (OUTER EAR) FOR APPLICATIONS IN UNDERSEA RESEARCH AND EXPLORATION

For a man to operate effectively in a marine environment it is essential that he retain the use of as many of his senses as possible. A number of research vehicles now under study place a man in the ocean in a transparent sphere. This retains effective use of his vision but completely decouples him from the ambient sound environment. The basic objective of the artificial pinna program is to recover this acoustic contact and provide effective binaural localization in the sea. Such localization would be of value in associating noise made by marine life with specific observed specimens. This would aid studies by marine biologists and also help characterize background noise data for sonar design.

A wide variety of sounds exist in the sea. Many of these extend well beyond the frequency range of human hearing. Fortunately it is possible to select frequency ranges of interest and translate them electronically into the audible range.

A large body of literature on human hearing exists and much work has been done to identify the mechanisms of binaural localization. A key result of this prior work is that the pinnae, or outer ears, play almost as important a role in localization as the basic interaural separation. Some previous attempts at Naval Weapons Center, China Lake, to provide underwater localization have actually used hydrophones mounted in a pair of big ears scaled in size and spacing by a factor of five, which marks the difference in propagation velocity between water and air. Such an approach is direct and intuitively appealing. Results, however, were indecisive. This is due partly to the difficulty of finding materials whose acoustic mismatch to water is equivalent to the mismatch which skin and cartilage present to air. A failure of direct scaling is also likely.

Initial artificial pinna work at NUC was based on a different approach. Rather than depending on reflections in a pair of large ears, hydrophones would sample the sound field over two regions corresponding to the ear locations. The necessary delays, phase shifts, and amplitude weighting would then be introduced electronically in combining the hydrophone signals into a pair of output signals as shown in Fig. 1. This approach looked promising since a sufficiently large number of spatial samples will completely characterize the local behavior of a sound field. A family of transversal filters which had been developed for sonar applications appeared to offer sufficient flexibility to simulate the necessary delays and reflections.

The initial study divided into two main areas. Computer simulations with an adaptive program were used to determine the ability of various sensor arrays to simulate specified spatial responses. Simultaneously an extensive set of measurements was made to characterize the time impulse response of the human pinna as a function of direction. Several problems became apparent. The simulation indicated that a vastly excessive number of degrees of freedom, and hence hydrophones, would be required

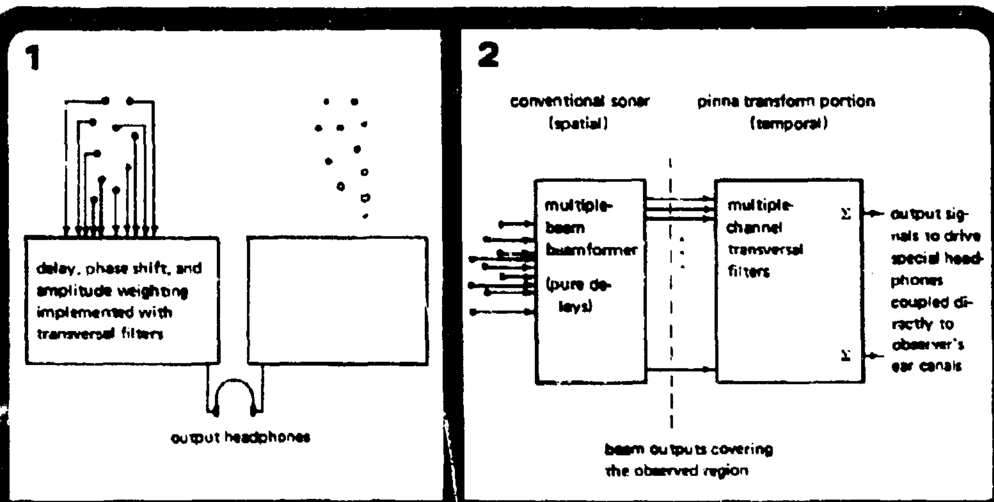


Fig. 1. Initial artificial pinna approach. Fig. 2. Separation of spatial and temporal portions of artificial pinna.

to directly simulate the required spatial response. The complicated coupling between geometric variables and time variables indicated by the pinna response measurements precluded direct use of existing sonar transversal filters. Detailed examination of the impulse responses indicated that at least a portion of the responses are separated by the ear on the basis of their time-scale expansion or compression. Although this is difficult to implement electronically for a response as complicated as the ear's, it appeared to hold promise for sonar arrays on submarines, since it would greatly reduce the hull penetrations required. This work is now in progress as the "ambiguity beamformer program" and may well prove to be the most valuable spinoff of the artificial pinna program.

The difficulty arising from the coupling of the spatial and temporal variables led to a reexamination of the problem to determine whether these variables were separable. Since the transversal filter can readily simulate the response of the pinna in any single direction, the direction discrimination must be performed at a prior point in the processing chain. The prior portion of the processing chain then becomes an array and multiple-beam beamformer of exactly the type now used in sonar. The array is required only to possess good directional properties, and no requirements for simulation of ear shape and spacing remain. Hence it should be possible to use a pinna transform adapter box to provide binaural localization with many existing systems. This approach is shown in Fig. 2. The multiple-channel processing, however, would require an excessive number of existing transversal filters. Within the next 2 to 3 years, multiple-channel transversal filters which will handle this task should be available. At least two promising candidates are now under development under other projects at NUC and the Naval Electronics Laboratory Center.

Present work is divided into three main areas. A large quantity of data is being reduced to derive pinna impulse responses over a hemisphere. A pair of interim experimental pods is now being constructed for experiments on the RV *Sea See*. A pair of special headphones is in final development for the system output. The impulse response data will determine the structure of individual channels of transversal filters for the final system. They will also provide a basis for future computer simulation.

The interim pods for the RV *Sea See* emphasize the interaural term rather than the pinna terms. Experience gained with this system will help to define the resolution required in future systems and will provide a good test of the special headphones. These pods should provide better localization than the existing *Sea See* system, which was installed under a number of limiting constraints. Hence it should prove useful to marine biologists who make extensive use of the *Sea See*.

The special headphones are designed to solve a problem which became apparent in the initial localization experiments. If conventional headphones are used the subject's own pinnae introduce confusing redundant delays. If a stethoscope type of headphone is used, similar problems are caused by closed-tube resonance effects in the observer's ear canals. These are the phenomena which cause the "inside one's head" sensation in using stereo earphones. The developmental headphones use insertion-type electrostatic elements with a diaphragm of sufficiently low mass not to cause closed-tube loading effects.

This is a transitional period for the artificial pinna program. The results of initial research have been assimilated and potential applications are in sight. Work is now progressing to develop the background required to utilize the multichannel transversal filters when they become available.

HYDRO-TRANSDUCER

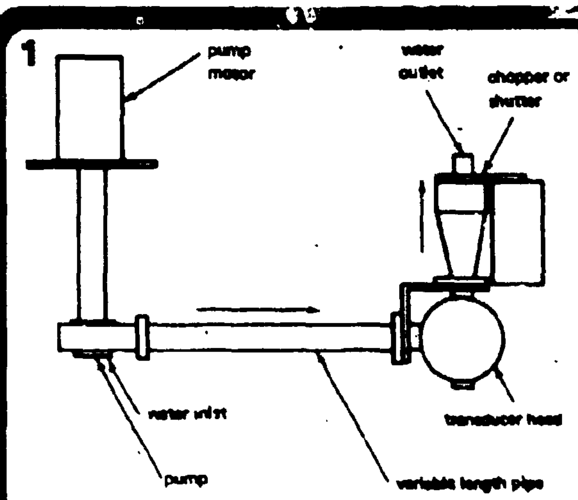
Sonar equipment has utilized electrostrictive, magnetostrictive, and other transducers to produce high-power, low-frequency acoustic signals underwater. Each of these systems has some characteristic which limits its usefulness. Size, weight, susceptibility to shock and seawater, hardware complexity, and electrical power requirements are some of the obvious disadvantages.

In an effort to simplify such systems while reducing costs and improving reliability, NUC has developed and tested a Hydro-Transducer which is capable of delivering low-frequency (below 100 Hz), high-power (in the order of 84 dB/dyne at 1 yard) signals and which uses simple, standard parts.

The Hydro-Transducer consists of a fully enclosed electric motor (40 hp, 60 Hz, 440 V, 3-phase, 1800 rpm) which powers a Model 4831 Deming sump pump (1800 gpm at 40 psi). Two low-mass, 21-in. domes and bellows assemblies comprise the transducer head. The dome and bellows assemblies are separated by a spacer which provides flanges for pipe connection. A variable-speed rotary chopper, with its own motor, completes the unit (Fig. 1).

The theory of operation is elementary. The pump sets up a high-volume, low-pressure flow of seawater through the transducer head. By means of the rotary chopper, the flow is interrupted at the desired frequency. The momentary stoppages produce pressure pulses in the flow that are transmitted, in the form of acoustic energy, to the surrounding water via the transducer head, whose bellows flex in and out in response to the fluctuating internal pressure.

The unit was tested in two configurations, one with the head bolted directly to the pump outlet (Fig. 2), the other with a 7-ft length of 6-in.-diameter pipe bolted between the pump and the head (Fig. 3). Tests were conducted at the NUC Transducer Evaluation Center (TRANSDEC) and the Morris Dam Test Facility. The tests at TRANSDEC served to shake down and debug the Hydro-Transducer. For these tests, the unit was suspended from a crane and positioned about 15 ft from the side of the test pool. The transducer head was submerged to a depth of 6 ft. Figure 4 shows the unit under test. Both pump and chopper are operating. The low height of the effluent above the level of the pool is an indication of the water going into the transducer heads and being converted into sound energy.



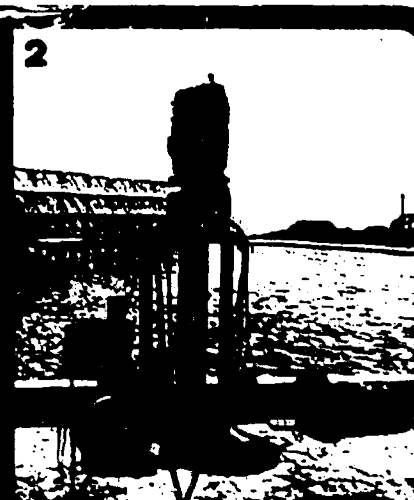


Fig. 1. Present hydro-transducer schematic (long assembly). Fig. 2. HUC hydro-transducer (short assembly).

The shakedown tests demonstrated that with the provision of strengthened dome and bellows assemblies and heavy springs to restrain dome travel, the Hydro-Transducer could operate successfully in each of its configurations. Recordings from a pair of hydrophones (one inside the transducer head, one 10 ft away at the same depth) revealed a close similarity between the two sets of pulse waveforms.

With the feasibility of the system thus established, tests were conducted at Morris Dam to measure the power and frequency of the transmitted sound. For these tests, the unit was lowered to a depth of 80 ft, and hydrophones were positioned at ranges of 2500 and 2800 ft. Operation was over the frequency range 10 to 125 Hz. Data showed the power (at 25 Hz) to be 84 dB/dyne at 1 yard, with

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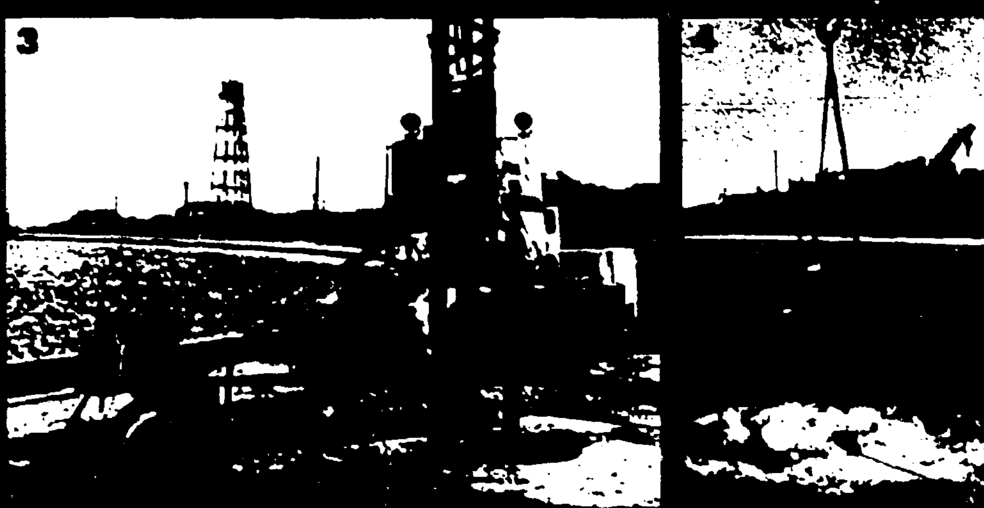
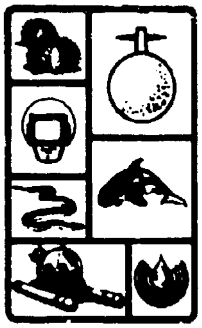
Fig. 3. NUC hydro-transducer (long assembly). Fig. 4. NUC hydro-transducer being tested at TRANSDEC. Pump and chopper are in operation.



an overall system efficiency of 0.25 percent at the primary frequency.

Future development of the Hydro-Transucer will include a larger radiator and a venturi feed for greater efficiency. Also, additional uses for the device, such as VLF communication, will be investigated.



FIBER OPTICAL TRANSMISSION

The ability to transmit data from point to point is becoming increasingly important. In the majority of underwater cases, the coaxial line performs adequately; but under conditions of restricted size or susceptibility to noise, the fiber optic transmission line shows improved performance. These lines consist of bundles of hair-like strands of glass which form flexible cables capable of conducting light.

The Navy Electronics Laboratory (San Diego) and the Naval Undersea Research and Development Center (San Diego) are jointly investigating the feasibility and utility of optically transmitting data underwater through a multipurpose cable. Such a cable would have strength enough to tow a sensor body, and would incorporate both an optical link, to transfer data to the tow ship, and all requisite electrical conductors.

This goal provides a realistic context in which to demonstrate newly developed low-loss fiber optic data transmission beyond the short samples so far seen in laboratories. Two large questions arise:

- What real data rates can be achieved at the multithousand-foot length?
- How can fine glass strands be combined within a metallic cable for use in the ocean environment?

Neither of these will be answered definitively, but only with respect to the specific application under study.

Optical signaling is hardly new. However, some of the tools have evolved with startling speed in the last 10 years. Light-emitting semiconductor diodes are small, cheap, reliable, and capable of multimegahertz operation. Figure 1 provides a view of relative sizes. New understanding of losses in optic fibers has permitted reduction of the attenuation level from 1000 dB/km to 100 dB/km for multimode fibers and 25 dB/km for single-mode fibers. It must be emphasized that these new fibers are in various stages of transition from laboratory prototypes to production devices. The manufacturers are unsure of themselves, and the product will probably change rapidly.

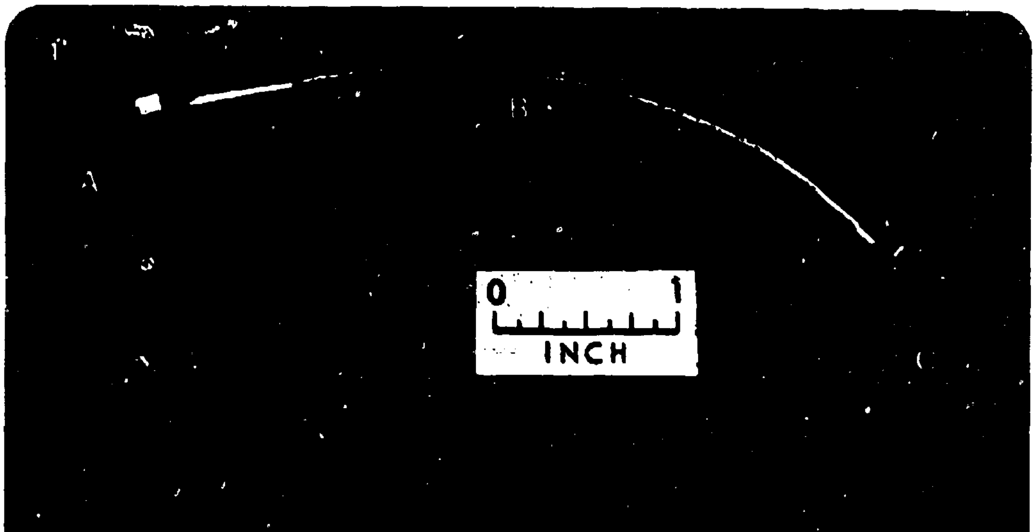
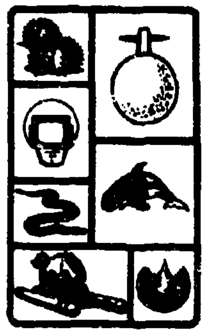
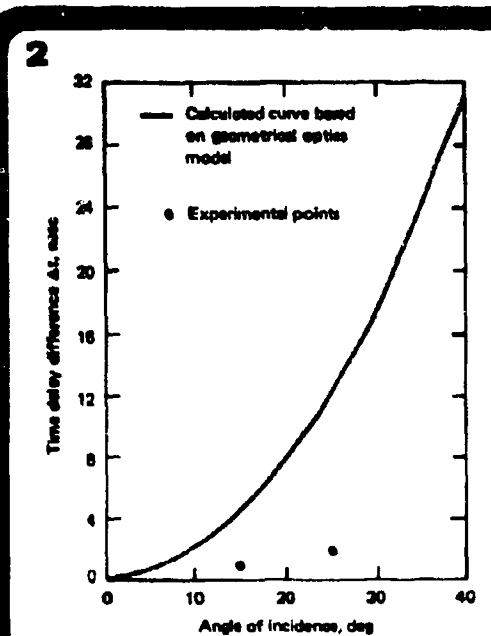


Fig. 1. Present scale of optical transmitting parts: (a) light-sensitive diode, (b) fiber optic bundle, (c) light-emitting diode.

The program at NUC is combining a miniature time-division multiplex system and pulse-code modulation in a towed sensor package. The optical data line is contained in the towing line. Testing will commence with a data rate of 5 megabits/sec. Initially, the line will be 1000 ft long, with 10,000 ft as the goal. Under contract, Corning Glass will provide, in 1000-ft lengths, bundles of fibers having losses no greater than 100 dB/km. Using this material, we will be able to measure data rates on actual long lengths, rather than extrapolate from short samples. A bench-type multiplex transmitter and receiver system is being assembled that will allow evaluation of the components. This is to be followed by a more realistic "wet system" to be towed in the ocean.





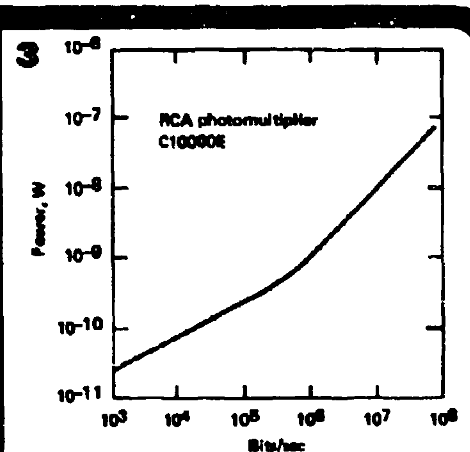


Fig. 2. Time-delay difference caused by change in angle of incidence (64-meter cable length). Fig. 3. Optical power at 9000 Å required for error rate $< 10^{-7}$ as a function of bit rate. (From Taylor, H.F. NELC TR 1763.)

Containing a light beam within a long glass filament is accomplished with a jacketed fiber. The outer jacketing material is of a lower refractive index than the central fiber. But glass fibers did not constitute a significant data-transfer tool until attenuation was reduced from 1000 to 100 dB/km for multimode fibers (50 to 80 μm diameter). The single-mode fibers of 2 μm diameter exhibit attenuation in the 25-dB/km range. This latter type is several years away from production. High material purity and uniform fiber diameter are the main mechanisms for improving transmission. Fibers of these extremely small diameters (2 μm with 20 μm cladding) require laser type sources to focus energy into their ends. Multimode fibers (50 μm diameter each) grouped to form a bundle 1.5 mm in diameter make a suitable area match for the light-emitting diodes.

Attenuation of the transmitted light within the fibers is one limitation on the data rates achievable with such systems. Another is pulse distortion, as a result of which two successive pulses may be broadened to the extent that they lose their discrete character. What occurs is that light rays launched at different angles experience different propagation times. A geometrical model (straight uniform cylinders of length L) predicts a ray propagation time.

$$T = \frac{\eta_1 L}{C}\left(1 - \frac{\eta_2^2 \sin^2\theta}{\eta_1^2}\right)^{1/2}$$

where

θ = angle between incident beam and fiber axis

η_1 = refractive index of core

η_2 = refractive index of medium from which ray enters fiber

C = velocity of light in vacuum

The longest propagation time occurs for the maximum acceptance angle, given by

$$\theta_a = \sin^{-1}\left(\frac{\sqrt{\eta_1^2 - \eta_2^2}}{\eta_a}\right)$$

where η_2 is the refractive index of cladding.

Geometry, however, does not predict the shifting of energy from one mode to another, lower order mode of lesser delay. Figure 2* shows measured delay differences vs angle of incidence in a 64-m line. By extrapolation to 1 km, the maximum delay is expected to be 60 nsec/km. In this sample of multimode fibers (64 meters long), 3.5-nsec pulse broadening was observed for the normally incident ray. Extrapolating to a 1-km bundle would yield 55-nsec pulse broadening. A bit rate between 10 and 20 megabits/sec for a 1-km line can be expected. Reported measurements made on samples 30 m long predict maximum bit rates from 5 to 30 megabits/sec in a 1-km line.† The planned measurements on 1000-ft lengths will provide more accurate definition of bit rates.

Comparisons with coaxial cables reveal important differences in behavior. Attenuation in coax rises with frequency, leading to equalization requirements for broad bandwidths. For optic fibers equalization is not needed. RG 58U exhibits 40 dB/km attenuation at 10 MHz, rising to 145 dB/km at 100 MHz. Attenuation in multimode fibers is less than 100 dB/km and independent of frequency. Increased bandwidth is

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*From Smiley, Taylor, Lewis, and Albares, Naval Electronics Laboratory Center

†From D. Williams and K. C. Kao, "Pulse Communications Along Glass Fibers," *Proc. IEEE*, Vol. 56, Feb. 1968, pp. 197-198.

achieved in coax by enlarging the cable diameter, whereas with fibers it is only necessary to provide enough fibers to cover the light source. A 1-mm-diameter bundle is sufficient when using a light-emitting diode.

Pulse distortion, in particular the spreading of pulses on transmission, limits the maximum possible bit rate. It should be noted that pulse spreading increases with the square of the line length for coax but only as the first power of the length for fibers. For coax this broadening is of the order of 1 μsec in 1 km, but only 55 nsec for a glass bundle of the same length, as noted above.

The optical data link whose suitability is under investigation allows only limited space for the transmitting light source; consequently the light-emitting diode (LED) was selected. A laser could deliver more power in a collimated beam, but cannot be accommodated physically. The LED is easily pulsed at 20 megabits/sec from low-voltage digital circuits. The LED's small linear dynamic range precludes amplitude modulation but leads naturally to on-off-coded modulation. Since pulse-code modulation instrumentation is readily available, this method was selected. Semiconductor lasing diodes are now available, but limited by internal heating to operation in the multikilohertz region.

The need for a minimum-noise receiver requires that a photomultiplier, as opposed to various semiconductor sensors, be used. The added size and high-voltage power supplies are not troublesome aboard ship, at the reception end of the line. Analysis by NELC* shows the best combination in the 5-megabits/sec range to be the TIL 24 emitting diode operating at 9300 Å, a bundle of fibers 1.5 mm in diameter, and the RCA C 3100 E photomultiplier used as a detector. Allowing for coupling losses, a probable error rate less than 10^{-7} can be assured if the line attenuation is no greater than 53 dB. Under these conditions, multimode fiber lines having an attenuation of 100 dB/km can be expected to operate to distances of 1/2 km without repeaters. For a fixed error rate, bit rates and received power will bear the inverse relation exhibited in Fig. 3.

Combining fiber bundles with load-bearing metallic cables is highly experimental. United States Steel Corp. has indicated their interest in attempting to include the bundles in the fabrication of conventional steel cables of the Amergraph variety. Since the fibers are weak in shear, it is expected that there will be unusual problems if conventional wire rope manufacturing machinery is employed. Two other approaches are being followed. The first combines optical fibers with continuous strength glass fibers made in a step-moulding process. The fibers are all bonded together in parallel in an adhesive resin. This provides a bundle of about the same diameter as a steel bundle of equivalent strength but one which has only half that weight in air. The second method builds up a glass rope from small strings of strength glass held in plastic, which are later twisted, along with optical fibers and electrical conductors, into ropes. Neither method is available commercially, and each presents many technical uncertainties, but they do represent an attractive alternative to steel cable if weight is an important consideration.

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*H. F. Taylor, "Transfer of Information on Naval Vessels via Fiber Optic Transmission Lines," NELC TR 1763, May 1971.

Behavior of glass fibers in ocean water is uncertain. Tests conducted several years ago by NELC on Glasstran* (twisted glass rope), showed that fibers lose tensile strength when exposed to salt water. Similar behavior has been noted by Bell Laboratories in the production of fiber optic strands. They start life with 300,000 lb/in^2 breaking strength, which quickly drops to 30,000 lb/in^2 in an air environment because of the water vapor present. The actual sheathing of the fibers and treatment for shipping and further manufacture is receiving little attention from the glass companies. Since the telephone system will, apparently, be the largest user, the manufacturers are limiting their concern to packaging for "land line" applications.

Concurrent with the optical cable testing is the evaluation of the data multiplex and encoding devices. The system is designed to allow growth to 100 data sources. These will be sampled sequentially and converted to a digital code for serial transmission over the glass fibers. Dynamic range and sampling rates require that 5 megabits/sec be transmitted. This is not expected to be the limiting rate for the fiber optics, but is high enough to begin testing its capacity. This data rate, however, does stretch present digital-conversion and magnetic-storage devices.

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*Packard Electric Div., General Motors Corp.

TRANSPARENT-HULL SUBMERSIBLE (THS), TO DEVELOP DEEP SUBMERSIBLE BUOYANT PRESSURE HULLS

The transparent-hull submersible MAKAKAI has been designed and constructed by the NUC Hawaii Laboratory as a two-man submersible vehicle that affords its operators maximum visibility by housing them in a transparent, spherical, acrylic plastic pressure hull. This vehicle is the culmination of a number of NUC programs: the development of transparent pressure hull materials, cycloidal propellers for submersible propulsion, pressurized electronics, and a soft-line information transmission system to eliminate or reduce the number of required penetrations of the pressure hull. MAKAKAI was developed to provide an actual operational evaluation of these systems and a useful vehicle for undersea work.

MAKAKAI's structure and configuration are intentionally simple and nonhydrodynamic. The pressure hull is mounted high to provide maximum unobstructed viewing for the operators. The shape of the vehicle resulted primarily from the central placement of the pressure hull, which provides the majority of the positive buoyancy for the vehicle. This configuration also provides an area forward of the hull for mounting test hardware, cameras, and the like. A prime factor in the overall vehicle sizing was the requirement that it be easily transportable by aircraft as well as by truck.

The acrylic pressure hull used on MAKAKAI was developed by the Naval Civil Engineering Laboratory and the Naval Missile Center for the Naval Experimental Manned Observatory (NEMO) Program. The hull has an outside diameter of 66 in. and a wall thickness of 2.5 in. Design depth is 1000 ft, with an actual short-term collapse depth of 4200 ft. A full-size prototype hull was tested to destruction, verifying this collapse depth. The pressure hull was fabricated by Swedlow Plastics Co. of Garden Grove, California, by bonding together 12 spherical pentagonal sections to form a full sphere. Two 4130-steel inserts are placed at the poles. The upper insert is the hatch for operator access, and lower insert serves as a penetrator mount and as the structural attachment point between the pressure hull and MAKAKAI structure. A 1/2-in.-thick acrylic cap has been placed around the main pressure hull to protect it from abrasion and any accidental impacts in or out of the water.

The pressure hull sits on four radially oriented pads which support its air weight. The structural link between the hull and the vehicle frame is a single 3/4-in.-diameter stainless steel cable. This cable transfers the hull buoyancy to the frame when the vehicle is submerged. The vehicle frame is a simple rectangular structure made from 4.5-in.-O.D. 6061-T6 aluminum tubing. The center cross structure serves as a sphere mount and adds rigidity to the frame. All tubes are free flooding and are painted internally and externally.

Electrical power for the submersible is provided by 6-V lead-acid golf cart batteries. Three voltages are available: 120, 30, and 6 V. Major propulsion power is drawn from the 120-V battery string, and the electronic systems operate from the

30- and 6-V battery strings. Batteries are located in two cylindrical battery pods, one on either side of the vehicle. Each pod contains all three voltages. The batteries are placed on trays which roll out of the pod for easy servicing. In use, the pods are closed, oil filled with transformer oil, to compensate to ambient pressure. Relief valves are provided in the pod to vent battery gassing. The battery pods are easily removed from the vehicle and can be replaced with pods containing freshly charged batteries if a short turn-around time is required. The battery pods are each attached to the vehicle by a single long eye bolt which passes down through the side support fin and screws into the pod strong back. Eyes at the top of the two bolts serve as the two prime vehicle lift points. For emergency ascent these eye bolts can be severed by an explosive cutter, causing either pod to drop.

Buoyancy control is provided by a variable-ballast system. This system provides buoyancy trim, pitch trim, and roll trim. A ballast tank is mounted on each corner of the vehicle. Each tank has a capacity of 200 lb of seawater. The overall buoyancy trim of the vehicle can be adjusted ±400 lb around neutral. The two ballast pumps pump water in and out of the tanks to adjust buoyancy trim. Water is pumped between fore and aft ballast tanks for pitch trim and onboard on one side of the vehicle and overboard on the other side for roll trim. The two pump and valve units, one supplying each side of the vehicle, provide a degree of redundancy in case of component failure. The nonwater volume of the ballast tanks is compensated to 10 to 20 psi above ambient pressure by air stored in four high-pressure cylinders. The high-pressure air is reduced to the required ambient pressure by a differential-pressure regulating system. The ballast tanks are provided with relief valves to vent air on ascent.

Life support is provided to the operators by a conventional system. Oxygen, stored in high-pressure cylinders mounted in the sphere, is bled into the hull interior through a pressure regulator and the flow is metered at the rate at which the occupants consume it. Carbon dioxide is removed by a Baralyme scrubber. Oxygen and carbon dioxide concentration are visually monitored from interior instruments to indicate any required adjustments in oxygen flow rate. Backup life support is provided to the operators by two closed-circuit breathing units. Each unit has a capacity of 36 hr. In use the occupant puts on a full face mask and breathes into it. The breathing circulates the system air through the scrubber, and oxygen is metered into the system, from a high-pressure oxygen cylinder. Each backup breathing unit has its own oxygen supply.

Use of a fully transparent pressure hull causes an atypical problem for submersibles. The hull material has a low heat transfer coefficient, and the transparent hull acts as a hot house by trapping solar energy, causing the interior temperature to rise. To reduce cabin temperature, MAKAKAI uses a simple cooling system. Thirty-five pounds of ice are stored in canisters under the operators' seats. Air is circulated over the ice by two small fans. The system is sufficient to keep cabin temperatures down to 85°F for 6 hours if precautions are taken to keep the hull covered until just prior to the dive. The cooling system also serves to remove water vapor from the cabin atmosphere by causing it to condense on the cool ice containers.

Propulsion for MAKAKAI is provided by two Kirsten Boeing pi-pitch cycloidal propellers. The cycloidal propeller is capable of directing its thrust in any direction in the plane of rotation of the propeller disc. The pi-pitch propeller is used because of its mechanical simplicity and the four-degree-of-freedom propulsive control that can be obtained by using two thrusters. The propeller operates like a paddle wheel. Thrust is generated by movement of the individual blades with respect to the water. The pitch of each blade is varied as it moves around its orbit so that the sum thrust of all blades is in the desired direction. Thrust direction is varied by changing the relative phasing of the blades with respect to the disc. By placing the two thrusters at 45 deg to the fore-aft vertical plane, four degrees of dynamic control (fore-aft, up-down, transverse, and yaw) are available. This is done by summing the thrust vectors. The coordination of the vectors is controlled by the pilot's hand controller, which directs the thrust resultant in the direction that the operator's hand is moved. The farther the hand is moved in that direction, the greater the thrust magnitude and vehicle speed. Drive for each thruster is provided by a variable-displacement hydraulic motor. Maximum motor speed is 550 rpm, while maximum propeller speed is 150 rpm. Speed reduction from motor to propeller is provided by a large rubber timing belt and appropriately sized belt gears on the motor and propeller.

On MAKAKAI the routine control signals (lights, propulsion, ballast system) are transmitted over a single optical (non-hardline) path from the hull interior to exterior. The advantage of this system is that it eliminates penetrators and their attendant problems. The MAKAKAI system can carry 64 bits of binary (on-off) information by means of three hard wires and the optical beam. The hard wires currently serve as clock and timing functions. A conventional hardware system would require 65 wires to perform these functions. All emergency functions are carried out of the pressure hull on hardwire penetrators. Emergency ascent modes consist of dropping a ballast weight, dropping either or both battery pods, or as a final backup, releasing the sphere via a mechanical rotary passthrough.

MAKAKAI was placed in the water for the first time in March 1971. At the present time it is undergoing checkout and testing in preparation for material certification. When this certification is obtained the Navy will have a unique vehicle which can economically and efficiently be used to perform many types of hardware or system tests where mobility and visibility are designed.

Pertinent vehicle characteristics are as follows:

Operating depth	600 ft
Crew	2
Length	18 ft 7 in.
Height	7 ft 6 in.
Width	8 ft
Weight	10,200 lb
Displacement	11,070 lb
Variable buoyancy	±400 lb
Submerged center of buoyancy-center of gravity separation	7 in.
Payload (including 2 operators)	870 lb
Max. speed	3 kt
Cruise speed	0.5–0.75 kt
Endurance	
Life support	12 hr, primary system 36 hr, secondary system
Power	2 hr at 3 kt 8 hr at 0.5 kt

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NUC FY 1972 INDEPENDENT RESEARCH AND INDEPENDENT EXPLORATORY DEVELOPMENT PROGRAMS

INDEPENDENT RESEARCH

Project Title	Principal Investigator	FY-71 Funding ($ X1000)	Key to NARDIS Report
Animal Attraction to Sunken Submarines	M. H. Salazar 213-449-7464 Code 25406	29	DN 034604
Detrimental Microbial Activities in Hyperbaric Facilities	P. R. Kenis 213-449-7464 Code 254	11	DN 134 618
Biological Degradation of Seafloor Supports	M. H. Salazar 213-449-7464 Code 25406	16	DN 134619
Effect of Deep Sea Bottom Animals on Ordnance	Dr. J. W. Hoyt 213-449-7471 Code 2501	9	DN 949319
Acoustic Propagation Analysis (in Sonar and Weapon Research)	Dr. L. A. Lopes 213-449-7721 Code 45	26	DN 034605
Shark Countermeasures for Protection of Navy Swimmers	Dr. C. S. Johnson 714-225-7839 Code 502	27	DN 949317
Study of Marine Mammal Population to Assist in Discrimination of False Sonar Targets (Formerly Cetacean Ecology)	W. E. Evans 714-225-7839 Code 502	53	DN 848445

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Project Title	Principal Investigator	FY-71 Funding ($ X 1000)	Key to NARDIS Report
Porpoise Sonar Simulation, an Approach to Improved Small Object Detection Sonar	W. E. Evans 714-225-7839 Code 52	17	DN 848444
Sound Production and Processing Mechanisms of Marine Mammals for Sonar and ASW Studies	Dr. S. H. Ridgway 714-225-7839 Code 502	55	DN 949322
Effect of Ocean Bottom Slope and Submerged Sea mounts on Underwater Sound Propagation (Sonar)	Dr. J. Northrop 714-225-7627 Code 503	39	DN 949321
Corrosion Chemistry at the Sea-Sediment Interface	Dr. S. Yamamoto 714-225-6340 Code 5045	52	DN 118746
Sound Scattering and Trace Element Distribution in the Sea	Dr. H. V. Weiss 714-225-6340 Code 5040	50	DN 118747
Ear Protective Research	M. Lepor 714-225-7916 Code 5056	4	
Nonacoustic Detection and Surveillance in the Deep Sea Utilizing Trace Chemistry	Dr. G. V. Pickwell 714-225-7829 Code 5046	27	DN 118748
In Situ Seawater Density Gauge System – A Neutron Densitometer	Dr. G. V. Pickwell 714-225-7829 Code 5045	61	DN 118742
Sonic Boom Underwater	Dr. R. W. Young 714-225-6881 Code 5050	6	DN 949315
Underwater Bioacoustic Sources	Dr. W. C. Cummings 714-225-6463 Code 5054	77	DN 848441

Project Title	Principal Investigator	FY-71 Funding ($ X 1000)	Key to NARDIS Report
Venomous and Dangerous Animals Affecting Naval Operations	Dr. G. V. Pickwell 714-225-7829 Code 5045	32	DN 118750
Wake Detection Study Program	E. J. Wesley 714-225-7879 Code 501	5	
Surface Wave Signal Processing for Sonar and Radar Systems and Other Applications	H. J. Whitehouse 714-225-6317 Code 6003	56	DN 034603
Two-Dimensional Optical Signal Processing With Applications to Sonar and Radar	J. M. Alsup 714-225-6871 Code 6005	37	DN 118751
Glass Study	W. R. Forman 74-225-6630 Code 65	40	DN 118725
Solidification and Supercooling of Seawater in Arctic Submarine Research	Dr. W. K. Lyon 714-225-6737 Code 90	32	DN 848447
Velocity and Attenuation of Sound in Liquids and Solutions for Sonar Research	Dr. E. W. Rusche 714-225-6851 Code 90	55	DN 848440
Marine Fouling	Dr. D. A. Wilson 714-225-6491 Code 04	75	DN ----- *

* Work being performed by the Paint Laboratory, San Francisco Naval Shipyard. Specific work unit data will be submitted by the performing Laboratory.

INDEPENDENT EXPLORATORY DEVELOPMENT

Project Title	Principal Investigator	Task Area	FY-71 Funding ($ X 1000)	Key to NARDIS Report
D'Artagnan	J. Wham 714-225-7412 Code 6005	ZFXX-112-001	106	DN 118763
Supercritical Combustion Gas Thermal Power Plant for Undersea Application	E. Karig 714-225-6496 Code 6005	ZFXX-412-001	53	DN 118764
Capsule Demonstration	James Bartling 213-449-602 Code 354	ZFXX-412-001	35	
Glass Study (Technology)	W. R. Forman 714-225-6630 Code 6523	ZFXX-412-001	77	DN 118725
New Vehicle and Sonar Concept Studies	Dr. T. G. Lang 714-225-6495 Code 6005	ZFXX-412-001	90	DN 118761
Saline-Operated Hydromotors	R. A. Nelson 714-225-6343 Code 6522	ZFXX-412-001	38	DN 118726
Reinforced Concrete Submersibles	E. N. Rosenberg 714-225-6862 Code 652	ZFXX-412-001	78	DN 118723

Project Title	Principal Investigator	Task Area	FY-71 Funding ($ X 1000)	Key to NARDIS Report
DEEP VIEW Submersible	W. R. Forman 714-225-6630 Code 6523	ZFXX-412-001	205	DN 848438
Transparent Hull Submersible (THS)	D. W. Murphy 808-261-4676 Code 6632	ZFXX-412-001	66	DN 848437
Adaptation of Head-Coupled TV to CURV	R. L. Watts 714-225-6343 Code 6522	ZFXX-412-001	2	DN 134620
Adaptation of Head-Coupled TV to CURV	P. L. Henderson 213-449-770 Code 2531	ZFXX-512-001	22	DN 134620
Sulphur Concrete for Submersible Hull Repair	J. H. Jennison 213-449-7301 Code 45	ZFXX-512-001	10	DN 134621
Flow and Optical Effects Produced by Mineral Platelets	P. J. Fetta 213-449-7318 Code 4522	ZFXX-512-001	17	DN 134622
Diver Armor	L. E. McKinley 714-225-7841 Code 502	ZFXX-512-001	33	DN 949305
Shark Dart	C. G. Blanc 714-225-7839 Code 502	ZFXX-512-001	21	DN 949307
Artificial Pinna (Outer Ear) for Applications in Undersea Research and Exploration	W. D. Squire 714-225-6317 Code 6000	ZFXX-512-001	71	DN 949310
Target Strength of Concrete Submarine Hulls	G. M. Coleman 714-225-7505 Code 6043	ZFXX-512-001	24	DN 118761
Acoustic Materials for Sonar and Acoustic Torpedoes	H. J. Whitehouse 714-225-7622 Code 6003	ZFXX-512-001	109	DN 118765

Project Title	Principal Investigator	Task Area	FY-71 Funding (S × 1000)	Key to NARDIS Report
Spherical Shell Acrylic Windows	J. D. Stachiw 714-225-7811 Code 6505	ZFXX-512-001	30	DN 118724
Glass Elevator	W. C. McSparron 714-225-6865 Code 6521	ZFXX-512-001	18	DN 018729
Hydrodynamic Transducer	S. A. Christie 714-225-6863 Code 6521	ZFXX-512-001	35	DN 949314
Special Warfare Targeting	R. L. Seiple 808-261-4676 Code 6533	ZFXX-512-001	30	DN 118727
Fiber Optical Transmission	J. T. Redfern 714-225-7505 Code 6044	ZFXX-512-001	69	DN 118800

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Young, Robert W., "Effective Duration of Sound from a Moving Source," *J. Acous. Soc. Am.*, Vol. 49, 1971, p. 101.

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Hall, J. D., W. G. Gilmantin and J. L. Mattsson, "Investigation of an Eastern Pacific Pilot Whale Stranding," IAAAM, 26-29 April 1971, Guelph, Ontario.

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NOTE: Listed dates are filing dates.

Beaucher, G. J. Quick-release mounting apparatus (U). Navy Case 49,425. 26 October 1970. UNCLASSIFIED.

Abstract: An underwater quick-release device for mounting a TV camera to a tripod on the ocean bottom.

Benefit to the Navy: Enables a diver to easily and quickly remove the camera from the tripod by the simple movement of a lever.

Blanc, Clarence G. Shark dart electronic circuit (U). Navy Case 50,632. 24 July 1970. UNCLASSIFIED.

Abstract: A compact electronic circuit has been designed for inclusion in the electric anti-shark dart to produce intermittent bursts of high-current, low-potential incapacitating power for prolonged periods of time.

Benefit to the Navy: The invention increases the effectiveness of the electric anti-shark dart to provide an effective means for neutralizing hostile marine creatures.

Fugitt, R. B. and Heckman, P. J., Jr. Extended-range polarization target (U). Navy Case 49,582. 18 March 1971. UNCLASSIFIED.

Abstract: A single-reflection or two-reflection retroreflective material is bonded to a target to make the target more readily visible, particularly under adverse conditions.

Benefit to the Navy: Objects which have been coated with this special type of surface, such as practice torpedoes, are more readily found after having been lost.

Gill, George Herbert. Carbon dioxide indicating meter (U). Navy Case 51,281. 3 December 1970. UNCLASSIFIED.

Abstract: Temperature-sensitive resistors are arranged in an electrical bridge in zero balance and connected to a source of constant potential for comparison between a standard sample of gas enveloping a first bridge resistor

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and a test sample of gas covering a second bridge resistor. Since CO_2 has a specific heat substantially different than air, an impedance change of the second bridge resistor, indicating a surplus of CO_2, will unbalance the bridge, causing a proportional readout on a meter.

Benefit to the Navy: The invention provides an indication of dangerous CO_2 buildup in a confined space such as a submersible interior to ensure the successful completion of a deep-submergence operation.

Gill, George Herbert. Voltage-controlled variable-duty-cycle pulse generator (U). Navy Case 51,292. 14 December 1970. UNCLASSIFIED.

Abstract: A pulse generator connected to a load has a variable duty cycle controlled by a selectively variable source of DC control potential. The invention conserves power and is of high reliability due to its uncomplicated electrical interconnections.

Benefit to the Navy: The invention has been installed in DEEP VIEW, and wider use should follow wherever battery power must be conserved and reliability is paramount.

Heckman, P. H., Jr. Cable-less television system (U). Navy Case 49,173. 3 December 1970. UNCLASSIFIED.

Abstract: The apparatus includes a laser which illuminates a target area, a TV camera tube which observes the area, and a light source modulator, connected between the laser and the TV camera tube, which modulates the light source in accordance with the variation in amplitude of the composite video signal generated by the TV tube.

Benefit to the Navy: The system does not require a cable or acoustic signals between the target and the remote viewing point.

Hirsch, J. Swimmer's tactile command navigation apparatus (U). Navy Case 50,923. 16 November 1970. UNCLASSIFIED.

Abstract: A diver's back pad which has perpendicular rows of tactile transducers which can be sequentially energized by a remote station to guide the diver through the water.

Benefit to the Navy: To navigate a diver to and from an underwater or surface station and communicate commands in regard to underwater work assignments.

Johnson, Clarence S. Anti-shark drogue dart (U). Navy Case 52,375. 24 March 1971. UNCLASSIFIED.

Abstract: A low-cost device for rendering a shark incapable of coordinated movements includes a metalic point joined to a miniature drogue chute. Upon embedding of the point in a shark, the chute fills with water and produces an equilibrium-upsetting drag.

Benefit to the Navy: The invention reduces the hazard posed by threatening

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marine creatures to increas the effectiveness of divers operating in dangerous waters.

Johnson, Clarence S. Full-view diver's mask (U). Navy Case 51,378. 15 October 1970. UNCLASSIFIED.

Abstract: A plate element is contoured to conform to a diver's face and mounts a peripheral resilient ring for sealing the mask's interior from the surrounding water. Wide-angle, distortion-free visibility is ensured and the dead air space is minimized to allow easier clearing and pressure equalization.

Benefit to the Navy: The invention increases a diver's field of vision to reduce diving hazards created by the tunnel-like visibility afforded by conventional masks.

Karig, Horace E. The supercritical thermal power system using combustion gases for working fluid (U). Navy Case 52,148. 9 June 1971. UNCLASSIFIED.

Abstract: Hydrocarbon fuel and oxygen are burned in a combustion chamber which directly feeds the exhaust gases to drive a turbine. The gases then pass through a regenerator and condenser for removing CO_2 and water vapor and are recompressed and fed back to the combustion chamber to lower the temperature of the burning gases now being fed to the turbine. Higher system efficiency is thusly realized and the danger of heat damage to the chamber or turbine is minimized.

Benefit to the Navy: The invention ideally lends itself toward application in submersibles needing power for prolonged periods of time.

Langguth, Arthur F. Anti-shark CO_2 dart (U). Navy Case 52,376. 16 April 1971. UNCLASSIFIED.

Abstract: An anti-shark dart includes a CO_2 cartridge held in a pressure-tight fitting having a hollow blade communicating with the fitting's interior. Inserting the blade into a threatening creature ruptures the cartridge and vents CO_2 into the creature's body via the blade. The injected CO_2 either immediately disables the creature or renders it incapable of self-control.

Benefit to the Navy: The invention provides a highly reliable, completely effe[illegible] device for countering hostile marine creatures. Widespread use of the invention should follow wherever such creatures are expected.

Lepor, Meyer. Noise protective device (U). Navy Case 51,671. 28 December 1970. UNCLASSIFIED.

Abstract: A flexible noise protective device is worn about the head of a crewman, head scarf style, and is formed of an outer sheet of rayon laminated on an inner sheet of tin-loaded vinyl. Inside the laminated sheet, fiberous glass creates a dead space to form an effective sound attenuation device that is comfortable and relatively weightless to allow its effective use while the wearer sleeps.

Benefit to the Navy: There has long been a need for a device which blocks out high-intensity ambient noise while being comfortable enough to allow its use for prolonged periods of time or during sleep.

Lindsay, G. F. and Whitehouse, H. J. Field-delineated acoustic wave device (U). Navy Case 49,426. 7 August 1970. UNCLASSIFIED.

Abstract: The interdigitated acoustic wave device includes a third electrode disposed between the conventional electrodes, the third, shielding, electrode improving the directivity of the generated surface wave.

Benefit to the Navy: The field-delineating electrode improves signal generation in multi-element applications, particularly where coded electrodes are used, and reduces cross talk between adjacent sets of elements.

Lopes, L. A., Jr. A strapped-down attitude reference system (U). Navy Case 50,019. 19 May 1971. UNCLASSIFIED.

Abstract: The system uses three accelerometers to obtain a vertical reference and two magnetometers to obtain the azimuth of the reference system.

Benefit to the Navy: The system is particularly useful for vehicles in the earth's gravitational field, where the reference provided by gravity is lost because of the vehicle acceleration.

Lopes, L. A., Jr. and Thomas, O. F. Digital camera (U). Navy Case 50,070. 18 June 1971. UNCLASSIFIED.

Abstract: Acoustic energy reflected from a target impinges upon an array of transducer elements, each of which corresponds to an element of the object acoustically observed. The magnitude and phase received at each element is mathematically operated upon, obtaining new magnitudes which, when applied to a printer, produce an accurate profile of the target.

Benefit to the Navy: The camera is able to distinguish between objects of the same size but different profiles, such as a whale and a submarine of the same size.

Means, R. W. and Whitehouse, H. J. Amplifying surface wave device (U). Navy Case 49,431. 22 July 1970. UNCLASSIFIED.

Abstract: A low-voltage battery is connected across the input of the surface wave device, which makes the device capable of amplification as well as transduction.

Benefit to the Navy: Amplification of input signals will permit more widespread use of surface wave devices for signal processing.

Parks, Bruce C. Telemetry-implanting pneumatic-powered harpoon (U). Navy Case 51,529. 2 August 1970. UNCLASSIFIED.

Abstract: A small dart is seated in the barrel of a pneumatic-powered harpoon and is expelled by valving a volume of pressurized air through the barrel's breech. A package of instrumentation or a float is pulled from a retaining

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device located at the barrel's muzzle to allow its being towed by a marine creature after the small dart has been embedded in it.

Benefit to the Navy: The invention provides a means for attaching instrumentation to marine creatures with minimal injury to the creature and with little risk to scientific personnel.

Rosenberg, Edgar N. Hydrodynamic transducer (U). Navy Case 51,377. 27 August 1970. UNCLASSIFIED.

Abstract: A freely flooded acoustic transducer includes a motor driving a centrifugal pump impelling water to an acoustic projector having a pair of oppositely facing radiating pistons. The impelled water passes through a disk-shaped slotted shutterwheel rotated by a variable-speed motor to create an "on-off" sequence, bidirectionally displacing the radiating pistons to project representative acoustic energy.

Benefit to the Navy: The invention eliminates complicated sealing assemblies, is non-responsive to ambient pressure variations, and projects a high-energy signal.

Rosenberg, Edgar N. SEAL (U). Navy Case 51,379. 24 August 1970. UNCLASSIFIED.

Abstract: An assembly for sealing a submersible interior along a glass hemisphere-hull juncture includes an annular chamber receiving the hemisphere's rim filled with oil and cooperating with a plurality of "O" rings to eliminate the buildup of failure-producing tensile stresses at the juncture.

Benefit to the Navy: Including glass as a structural member along with steel or other dissimilar materials has obvious advantages. The invention provides a way to achieve a glass-to-metal joint and benefits the development of a deep ocean technology.

Strapp, J. P. and Cornford, N. E. Apparatus for determining the presence of a vessel by detecting its wake (U). Navy Case 49,787. 5 March 1971. UNCLASSIFIED.

Abstract: A test TC junction mounted on a submersible tow monitors the temperature of the water, whereby a marked deviation in the temperature of the water from a static value, indicating the presence of the wake of a vessel, is detectable on the scale of an electrical instrument.

Benefit to the Navy: Wakes of either surface vessels or underwater vessels, such as submarines, may be detected by this means.

Strapp, J. P. A homing system for the acquisition of a sea-going target vehicle by detection of its wake (U). Navy Case 49,788. 29 April 1971. UNCLASSIFIED.

Abstract: The system includes a horizontal and vertial pair of test thermocouple junctions and means for guiding the missile in a horizontal direction and in a vertical direction. When the thermocouple junctions detect the wake of a sea-going vehicle, the missile is guided in azimuth and elevation toward the vehicle.

Benefit to the Navy: Naval countermeasures find detection and homing systems particularly useful.

Whitehouse, H. J. Surface wave devices for signal processing (U). Navy Case 52,524. 3 February 1971. UNCLASSIFIED.

Abstract: The device includes coded interdigitated electrodes and a logical circuitry which determines the manner in which incoming pulses are processed by the electrode structure, the device serving as a time compressor or delay line.

Benefit to the Navy: The device permits compact processing of digital data.

Whitehouse, H. J. Feedback-type acoustic wave devices (U). Navy Case 52,525. 4 February 1971. UNCLASSIFIED.

Abstract: The distributed-transducer device includes a feedback loop from the output transducer to the input transducer, thus permitting positive or negative feedback, as desired.

Benefit to the Navy: The negative feedback version may be used as a delay line, while the positive feedback version may be used as a clock oscillator, both embodiments being capable of being mounted on the same substrate, thus permitting compact signal processing of binary data.

APPENDIX

NONMILITARY APPLICATIONS OF INDEPENDENT RESEARCH AND INDEPENDENT EXPLORATORY DEVELOPMENT

IMPROVED FIRE-FIGHTING CAPABILITY

Under the IR program, a study of the effect of dissolved high-polymer substances on pipe-flow friction coefficients [illegible] small amounts (a few parts-per-million) were found to reduce the friction loss by over two-thirds.

One immediate application of this research is the development of fire department pumpers having the ability of producing greatly increased water flow rate, or further throw of the fire stream, with the same engine power. Alternatively, smaller, more easily handled hoses could be used to give the same water flow as the standard hoses now used.

As a result of this research, the New York City Fire Department[1] has been operating an experimental pumper using a polymer identified in the IR study, poly(ethylene oxide), as a drag-reducing substance. It is planned to include polymer capability in a new buy of 80 pumpers for the New York Fire Department.[2]

Currently, the Los Angeles Fire Department is considering use of polymers for mountain fires, where long lengths of small hose are required. The results of the IR program are being made available for this study.

IMPROVED TEST PROCEDURES IN TOWING TANKS

Under the IR program, a study was begun on the properties of exudates from marine phytoplankton and bacteria. It was quickly realized that many microscopic marine algae exude high-polymer metabolic products into the water and that these materials were extremely effective drag-reducers in turbulent flow. Freshwater algae were also found to be effective in reducing the drag significantly (50% or more in cultures).

In towing tanks, unexplained fluctuations in test results were so common that a special word, "storm," was coined for periods when the measured drag was far lower than the expected. Although much concern was expressed,[3,4] no expla-

[1] "Rapid Water - Fri[illegible] on [illegible]," *Fire Engineering*, January 1971, p. 33.

[2] "Slippery Water Cuts Friction Loss," *Fire Engineering*, September [illegible].

[3] Newton, R. N., "Standard Model Technique at ASW, Haslar," *Trans. Royal Inst. of Naval Architects*, London, Vol. 120, 1960, p. 435.

[4] Barnaby, K. C. and A. L. Dorey, "A Towing-Tank Storm," *Trans. Royal Inst. of Naval Architects*, London, Vol. 107, 1965, p. [illegible].

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ation for towing-tank "storms" was available until this research showed that algae and bacteria in the towing tank could, if given sufficient light and nutrients, produce a drag-reducing exudate solution in the tank. Day-to-day variation in drag results was also common.

As a result of the research showing the possibility of algae changing the drag in towing tanks,[5,6] many towing tanks have adopted greatly improved standards of water quality, and it is now believed that data reproducibility from towing tanks, with consequent improvement in commerical and Navy ship powering predictions, will be considerably enhanced. Further, should a "storm" occur, effective means of dealing with it (oxidizing the metabolic products with chlorine or hydrogen peroxide) are now on hand.

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[5] Hoyt, J. W., "The Effect of Algal Contaminants on Frictional Resistance," *Proc. 11th International Towing-Tank Conference*, Tokyo, 1966, p. 88.

[6] Hoyt, J. W., "An Examination of Some Towing-Tank Algae," *Proc. 12th International Towing Tank Conference*, Rome, 1969.

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13. ABSTRACT

This report presents brief summaries of a few of the independent research and independent exploratory development projects conducted at NUC. The projects described are animal attraction to sunken submarines, porpoise sonar simulation, venomous and dangerous animals affecting naval operations, reinforced concrete submersibles, adaptation of head-coupled TV to CURV, artificial pinna, hydrodynamic transducer, fiber optical transmission, and transparent-hull submersible.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
artificial reefs						
porpoises						
echo ranging						
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CURV						
television cameras						
submersibles						
concrete casting						
outer ear						
underwater sound						
transversal filters						
transducers						
sonar						
fiber optics						
data transmission						
towing lines						
multiplex						
coaxial cables						
perception						
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optical communication						
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