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# PROJECT DEEP OPS EQUIPMENT DEVELOPMENT

by

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## ADMINISTRATIVE INFORMATION

This report describes the special equipment developed for use with pilot and killer whales that are employed in Project Deep Ops to aid in the recovery of objects from the ocean floor. The equipment was developed for the Bio-Systems Division of NUC, which conducted the Deep Ops project under the direction of the Naval Ordnance Systems Command. This report, which describes work performed at NUC, Hawaii, between September 1969 and December 1970, was reviewed for technical accuracy by Clark Bowers and Scott Henderson. Marine mammal training and overall details of Project Deep Ops are described in a separate NUC report.

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## SUMMARY

This report describes the special equipment developed in support of Project Deep Ops, the objective of which was to determine the feasibility of using trained pilot and killer whales to aid in the recovery of pingered objects from the ocean floor and to ascertain at what depth such recoveries are possible.

The hardware requirements of the Project Deep Ops program were for a mouthpiece–grabber assembly, a practice target, a backpack, and a transport system. The first three of these requirements were satisfied by the design, fabrication, and testing of prototype hardware. The transport system requirement was met through the design, fabrication, and testing of a stretcher and an in-water launch and recovery device, and through the design only of a surface transport box. The feasibility of such a transport system was demonstrated with a functionally identical system that was used to transport a killer whale from California to Hawaii in January 1970.

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13 ABSTRACT

This report describes the special equipment developed in support of Project Deep Ops, a program to determine the feasibility of using trained pilot and killer whales to aid in the recovery of pingered objects from the ocean floor. The major pieces of equipment developed were a mouthpiece, a target attachment device, a practice target, a backpack, and a transport system.

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## CONTENTS

## INTRODUCTION

The purpose of this report is to document the special equipment which was developed for Project Deep Ops. The objective of Project Deep Ops was to determine the feasibility of using trained whales to aid in the recovery of pingered objects from the ocean floor and to ascertain at what depths such recoveries are possible. The hardware described in this report is a result of the combined efforts of the Bio-Systems Division, which conducted Project Deep Ops, and the Ocean System Division. Other aspects of the program, including the training and some of the background that led to the equipment developed, are discussed in a separate report.*

As in any research and development effort, the development of the hardware was a cyclical process. The project personnel from the Bio-Systems Division normally provided the requirements as they related to the animal and program needs, including some ideas for the methods that might be usable. Then through joint discussions between Bio-Systems personnel and the engineers of the Ocean Systems Division, the type of hardware necessary to satisfy these requirements was agreed upon. The hardware was then developed and built, and subsequently was evaluated in use with the animal. Very often this resulted in a changed concept or a change in the hardware. The final result, then, was that all the requirements were met either by (1) the initial design of the hardware, (2) a redesign of the hardware, or (3) the removal of the requirement due to increased knowledge gained during training.

In this report a description of the general and specific requirements will be followed by a description of the hardware design which satisfied these requirements. The major items of hardware developed were a mouthpiece–grabber assembly, a practice target, a backpack, and a transport system. A previous report by the authors contains additional calculations and descriptions of equipment which were developed in the interim approach to the problems but which were not selected for the final hardware design.**

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* Naval Undersea Research and Development Center, San Diego. Project Deep Ops: deep object recovery with pilot and killer whales, by C. A. Bowers and R. S. Henderson. (In process.)

** Naval Undersea Research and Development Center, San Diego. Deep Ops equipment and development, by G. W. Ching and H. O. Porter, November 1971. (NUC TN 644.)

## GENERAL REQUIREMENTS

The approach taken in Project Deep Ops was to train pilot and killer whales to mark targets on the ocean floor, develop the hardware required for recovery, and continue to run experiments to determine at what depths such recovery is feasible.

In order to recover a target, one of the major pieces of hardware which had to be developed was a mouthpiece and grabber assembly. The mouthpiece is the device that fits in the whale's mouth and allows him to carry a grabber device that attaches to the object to facilitate recovery. Two types of grabbers (practice and prototype) were developed, each using the same mouthpiece. The practice grabber differed from the prototype grabber in that it did not lock onto the target but rather floated to the surface. The practice grabber thus made it possible to run many consecutive training cycles without having to recover the grabber and target after each run.

Several designs of the prototype grabber were made, and one of these was fabricated. When properly actuated, this grabber latched onto the target, separated from the mouthpiece, and released a float which carried a line to the surface. Additional investigations were made into the feasibility of using a hydrazine gas generator instead of a line to bring the target to the surface. A hydrazine gas generator system was developed and will be covered in a future report.

In addition to the mouthpiece and grabbers, a practice target was needed to demonstrate the feasibility of recovering pingered objects from the ocean floor. Three types of practice targets were developed: a hard-wire target, an acoustically controlled target, and a continuous pinger target. The hard-wire target contained a pinger and a hydrophone connected to and controlled from the surface. The acoustically controlled target contained a pinger that could be turned on or off from the surface and a detector circuit which was activated if the whale impacted the target. The continuous pinger target contained a pinger which, manually activated, operated continuously until manually removed.

A backpack was developed for mounting equipment on the whale. It was specifically designed for carrying a radio transmitter as a precautionary device for tracking an escaped whale or a whale that swims out of visual contact. The radio was to be activated whenever the whale surfaced.

In order to demonstrate the feasibility of using whales to facilitate object recovery, it must be possible to move whales in and out of an area. To this end a transport system was developed. The major components of this system were a device to get the whale in and out of the water and a transport container to provide the animal with a comfortable environment during the actual transport.

## HARDWARE DEVELOPMENT

### Mouthpiece-Grabber Assembly

The mouthpiece-grabber assembly (Fig. 1) consists of a mouthpiece custom-fitted for each animal, a grabber, and a release mechanism which connects the two and holds the system firmly together until the whale impacts the target. One half of the release mechanism is incorporated in the mouthpiece and one half in the grabber. The combination of the mouthpiece, release mechanism, and grabber is positively buoyant.

Several mouthpieces (for different whales) are shown in Fig. 2. The mouthpiece consists of a ¼-inch-thick aluminum plate contoured to the general shape of the whale's mouth. The outer edge of the aluminum plate is bordered with syntactic foam (3 inches wide by 3 inches high). On both sides of the aluminum plate (where the whale will bite) is a 3/8-inch-thick neoprene pad covered with a 1/16-inch-thick layer of diaphragm rubber laminated to the neoprene. The diaphragm cover provides a tougher and more durable biting surface than the neoprene alone. The release mechanism is bolted onto the front of the mouthpiece. Further development of a mouthpiece with a polypropylene rather than an aluminum biteplate is described elsewhere.*

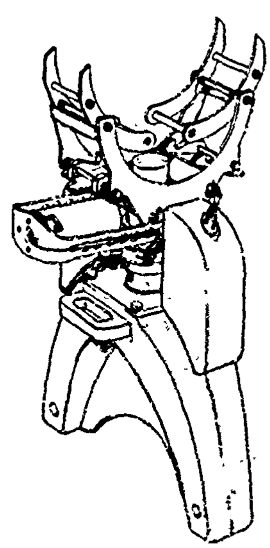

Figure 1. Mouthpiece and grabber assembly.

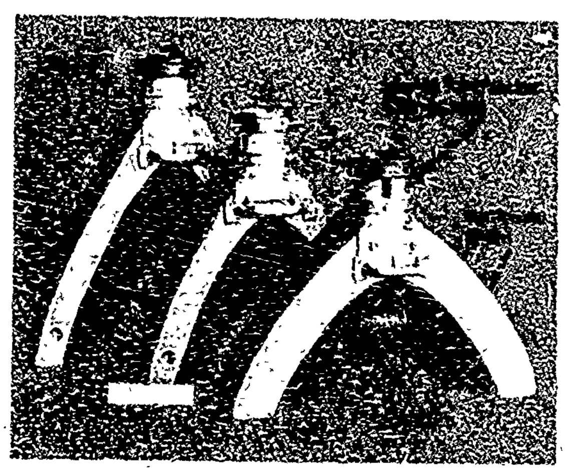

Figure 2. Mouthpiece designs.

* Bowers and Henderson, *op. cit.*

Upon proper actuation by target impact, the release mechanism must separate the grabber and the mouthpiece. The final release mechanism design is shown in Fig. 3. It uses a modified air hose quick-disconnect fitting that is mounted in two 3½-inch-diameter aluminum sections (hereafter referred to as the forward barrel and the rear barrel). The forward barrel has a spring-loaded plunger and a ¾-inch-thick plunger stop plate. Attached to the plunger stop plate is the male portion (plug) of the air hose quick-disconnect fitting. The rear barrel has a sliding receiver plate to which the female portion (socket) is attached. On each end of the barrels is a polypropylene collar to ensure proper alignment when the two barrels are linked together. The rear barrel collar has external threads machined to it to receive an adjustable tension collar. After the socket and plug from both barrels are mated, the tension collar is adjusted up against the socket sliding collar. The adjustable tension collar eliminates the looseness in the linkage of the two barrels and provides a firm connection.

The animal actuates the mechanism by depressing the spring-loaded plunger against the intended target. The plunger pushes the quick-disconnect socket sleeve back, which causes a set of pins to drop out of position, and this in turn allows the plug to be released.

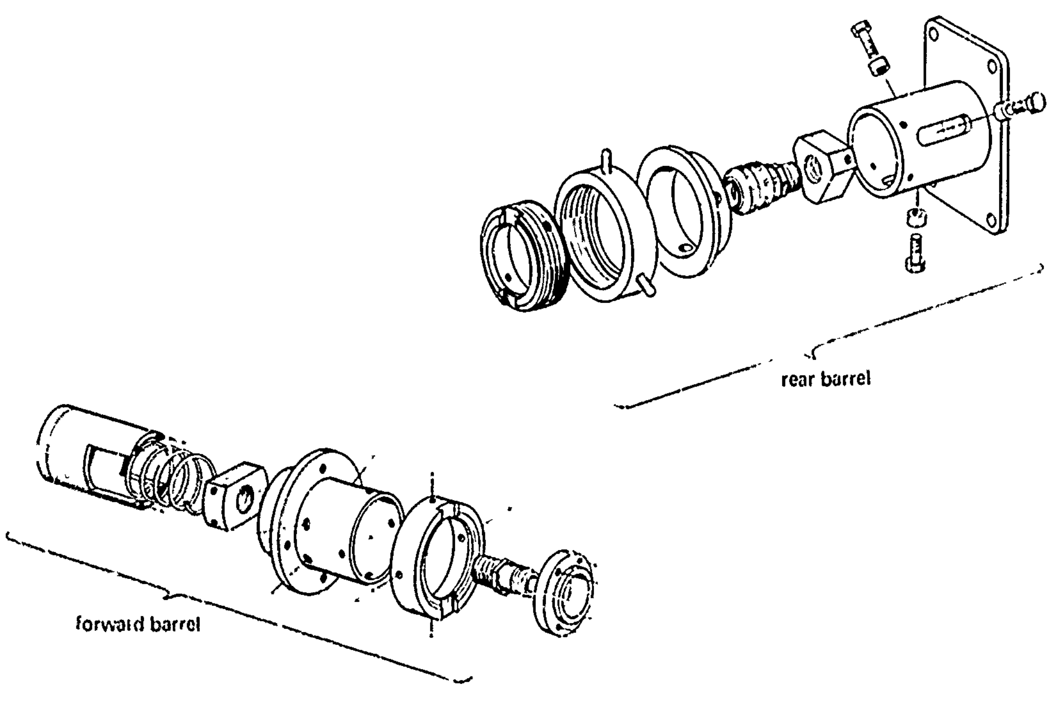


Figure 3. Final release mechanism.

The practice grabber, constructed of nylon for light weight, is shown in Fig. 4. The arms of the practice grabber serve to "guide" the whale to the proper orientation for the attachment. When the release mechanism is actuated, the practice grabber floats to the surface. The final prototype grabber (Fig. 5) differs from the practice grabber in that its arms lock onto the target upon proper actuation. In addition, a float attached to a retrievable line is released and floats to the surface. The target can then be recovered by a surface vessel.

Figure 4. Mouthpiece with practice grabber.

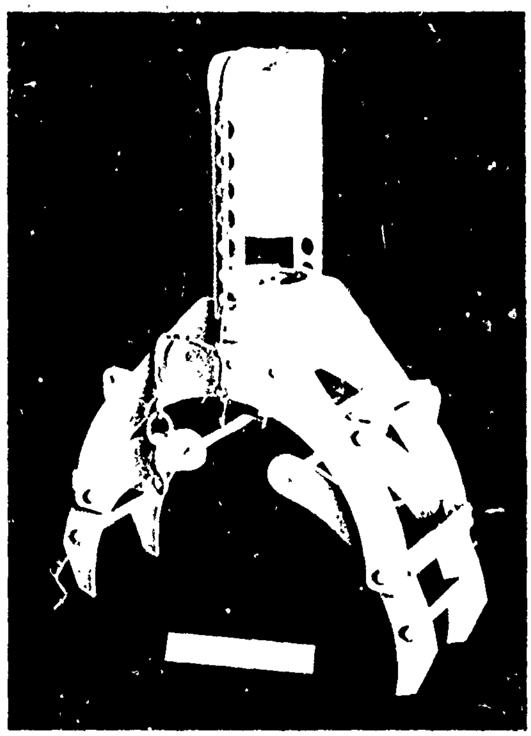

Figure 5. Final prototype grabber.

The final prototype grabber has been in continuous use in training sessions for several months on an almost daily basis. Experience to date has shown the design to be very successful for depths of a few hundred feet. A hydrazine gas-generator lift system for deeper recovery (up to a few thousand feet) has also been developed. Additional design details of the practice and prototype grabbers are available in another report.*

* Ching and Porter, *op. cit.*

## Practice Targets

The target specified for the Deep Ops project is a 12¾-inch-diameter cylinder about 6 feet long, containing a 9-kHz pinger. It was necessary to keep the air and in-water weight of the target low enough for two men to handle the target. As previously mentioned, three practice targets were developed: a hard-wire target, an acoustically controlled target, and a continuous pinger target.

The hard-wire target uses an electrical cable from the surface to the target. Inside the target are a 9-kHz pinger and a hydrophone. The surface unit contains the power supply, on–off switches, and a speaker connected to the hydrophone. The target itself is simply a rolled sheet of metal. The components of the system are shown in Fig. 6 and 7. In operation, the target system is controlled by a surface operator. Upon signal from the trainer, the operator turns the pinger on. He then listens for the pinger and the grabber impact with the target. When he hears the impact he turns the pinger off and signals the trainer.

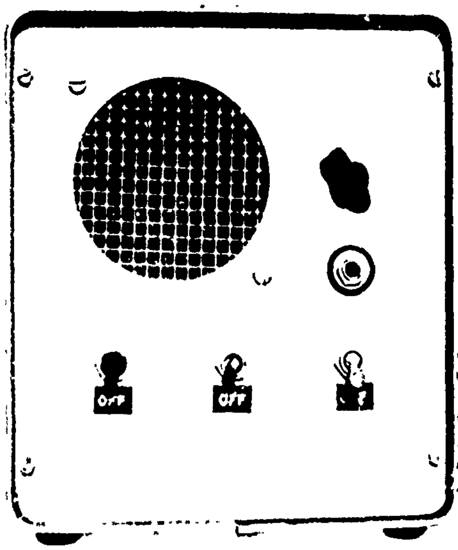


Figure 6. Surface controller for hard-wire target.

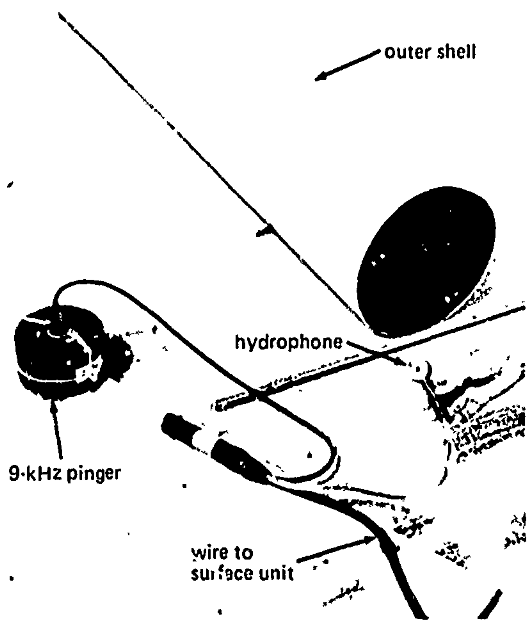


Figure 7. Underwater components of hard-wire target.

The acoustically controlled system (Fig. 8) operates in the same manner, except that the on-off functions are coded into the surface control panel, and the klunk detector (an impact sensing switch) automatically turns the pinger off.

Due to the unreliable performance of the acoustically controlled system, a continuous pinger target was constructed. This target contains a pinger (Fig. 9) that is activated on the surface and is placed overboard. When the training session is over, the target is recovered and the pinger is turned off.

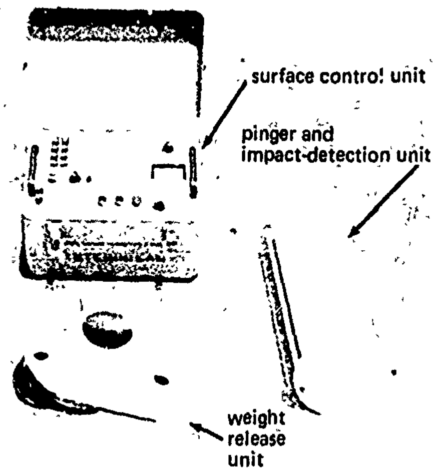


Figure 8. Components of the acoustically controlled target.

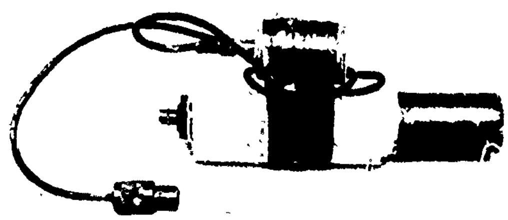

Figure 9. Continuous pinger.

## Backpacks

The development of a suitable harness or backpack for a whale is a difficult task. The purpose of the backpack-harness is to facilitate attachment of hardware to the whale in various places. The most significant piece of hardware to be attached is a radio transmitter device used to track the whale (Fig. 10). This transmitter-auto-

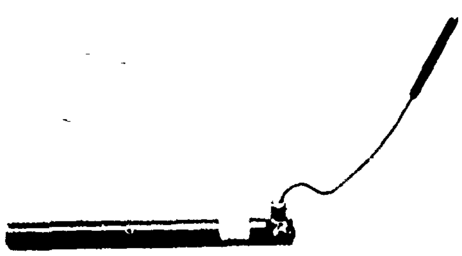

Figure 10. Radio transmitter.

matic direction finder system, developed at NUC, San Diego, by W. E. Evans for the tracking of wild marine mammals, was modified slightly under Project Deep Ops for daily use with trained whales.*

The first series of backpacks was developed for the pilot whale. The original design was a turtle-like shell with an elongated opening on the topside to fit over the whale's dorsal fin. A 3-inch belly-harness strap, along with a mechanical ratchet-type buckle to tighten the strap, was used to secure the backpack to the animal. After the backpack was used for a short period, an unusual problem occurred. The pilot whale developed an undesirable rubbing behavior when the pack was mounted on his dorsal fin. After experimenting with various designs for this animal, the final design shown in Fig. 11 was developed. It consists of a triangular-shaped nylon plate approximately 3/16 inch thick with 1-inch-wide nylon straps to fit around the animal's pectoral fins. The radio transmitter is mounted directly on top of the nylon plate.

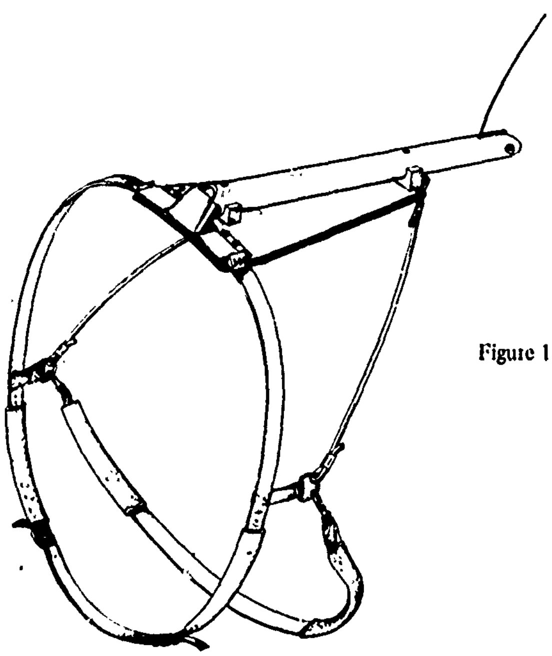

Figure 11. Pilot whale backpack.

The backpack developed for the killer whale is an evolution from one of the variations developed for the pilot whale. A casting was made of the pilot whale's

* Evans, W. E. Orientation Behavior of delphinids: radio telemetric studies. *In:* Orientation: sensory basis, ed. by Adler, H. E. Annals of the N.Y. Academy of Sciences, vol. 188, pp. 142-160, 1971.

dorsal fin and adjacent back area (Fig. 12). This casting was used as a guide to construct a plastic dorsal fin backpack for the killer whale (Fig. 13). The backpack is formed with two sheets of ¼-inch-thick polyvinyl chloride. Both sheets are contoured to the whale's back along the base of the dorsal fin. The sheets are then joined together with 3/16-inch-thick nylon sheets on the front and rear ends. The underside of the backpack is lined with ¼-inch-thick neoprene foam rubber. The 3-inch belly harness strap and mechanical ratchet-type buckle that was used on the original pilot whale pack is incorporated on this backpack. Adjustable screw clamps are used in two locations to mount the radio transmitter on one side of the backpack. This backpack–harness arrangement is then strapped onto the killer whale in a fashion similar to a saddle (Fig. 14).


Figure 12. Casting of pilot whale's dorsal fin.

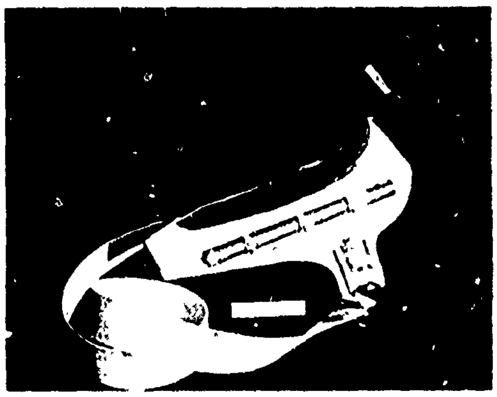

Figure 13. Killer whale backpack.

Figure 14. Backpack on a killer whale.

**Transport System**

The transport system is required to move the whales from one location to another with maximum safety for the whale and handling personnel and maximum comfort for the whale when out of the water. The out-of-water system must incorporate an adequate water-spray cooling system to allow the whale to remain out of the water for 16 hours. The transportation system must allow for air (C-141), truck, and barge transport. The whales to be transported were of two sizes. The killer whales to be moved were 17 to 19 feet long and weighed up to 6000 pounds; the pilot whale was approximately 13 feet long and weighed approximately 1500 pounds.

The transport system is divided into three major components: the stretcher, the in-water launch and recovery device, and the surface transport box. Each of these components is discussed below.

**Stretcher.** The stretcher used for the whales is an evolution of a previous stretcher used for porpoises. Basically it is a canvas stretcher with holes for the pectoral fins and a cut-out section to accommodate the thinner tail section. This canvas stretcher is padded with cotton mattress pads on the side toward the animal. The entire stretcher is mounted on steel stretcher poles. Figure 15 shows the killer whale stretcher, and Fig. 16 shows the killer whale in the stretcher.

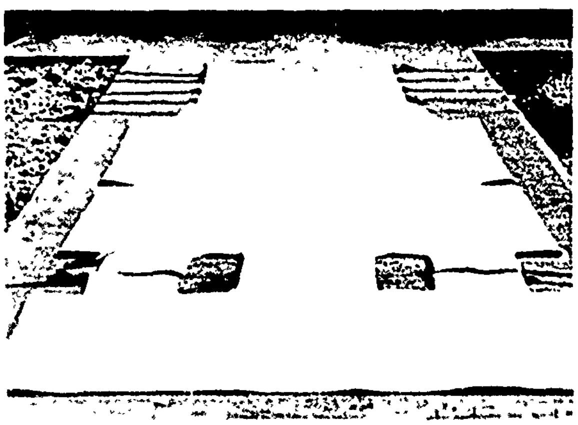

Figure 15. Killer whale stretcher.

Figure 16. Killer whale in stretcher.

**Launch and Recovery Device.** The final version of the pilot whale launch and recovery device (Fig. 17) was also used as a stretcher training device for the killer whales. It consists of 10 oil drums for flotation, two wooden walkways for handlers, an overhead pipe frame, and a hand winch and cables attached to the stretcher for raising and lowering.

The final version of the killer whale lifting device (Fig. 18) is functionally identical to the pilot whale lifter. The larger pontoons (available from another program) are used for additional buoyancy. The framework is aluminum to keep the overall system weight down and to be compatible with the pontoons. The winching system was originally designed for hand operation, but this proved to be unsatisfactory. Therefore, an electric winch (Pacific Hoist Electric Winch, model 64 WA) powered by two 12-volt batteries is used.

Figure 17. Pilot whale lift device.

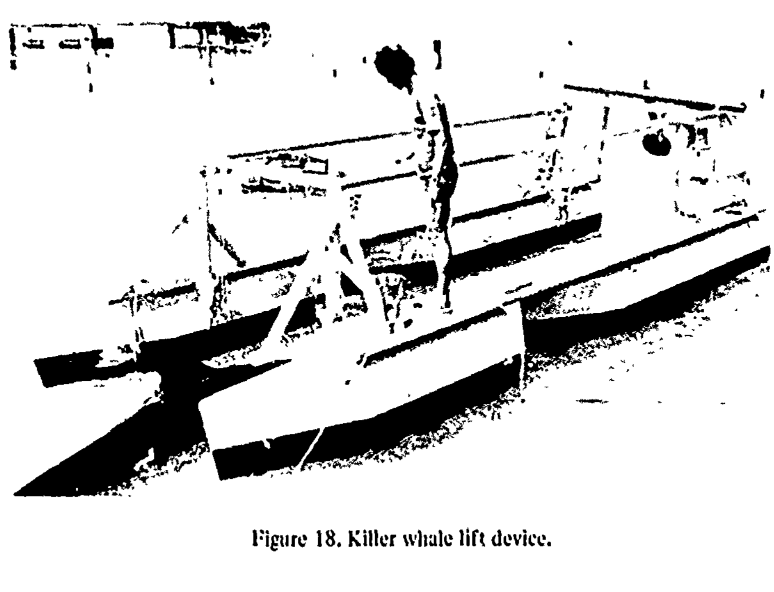

Figure 18. Killer whale lift device.

**Transport Box.** A box was designed to hold the whale in a stretcher (Fig. 19). A recirculating water spray system uses a 6-volt battery to drive a bilge pump. The output of the bilge pump is connected to a hose which can be sprayed directly onto the animal or plugged into a "shower" hose system suspended above the whale. The transport box was not fabricated at this time, since there were no plans to move any of the whales in the near future. However, a killer whale had been previously transported (in January 1970) from California to Point Mugu in a functionally identical box.

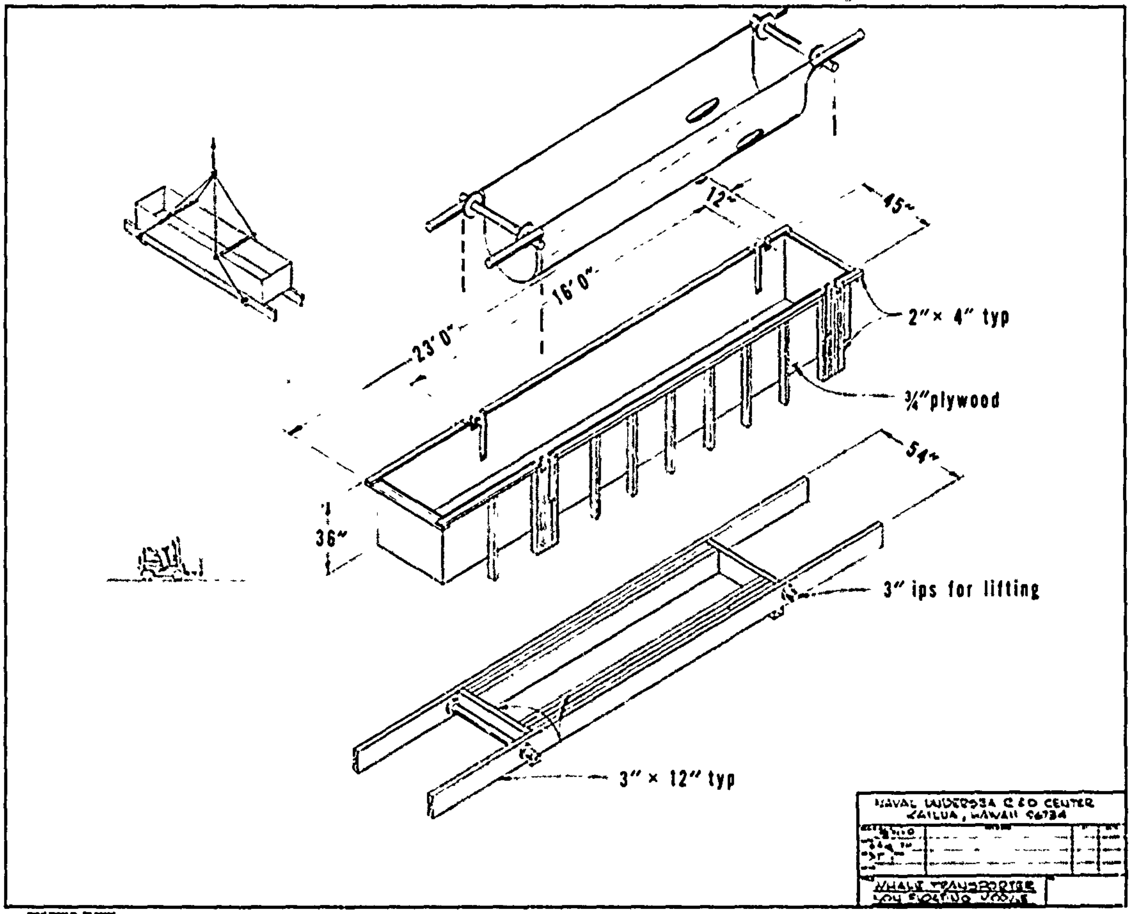


Figure 19. Whale transporter-nonfloating module.

## CONCLUSIONS

1. Operational hardware can be built for pilot and killer whales which allows them to perform tasks associated with target recovery.

2. The use of mouth-held hardware for whales is feasible.

3. Several types of backpacks allowing attachment of various equipment can be built for killer and pilot whales.

4. Pilot and killer whales can be transported over long distances (proven up to 3000 miles) with appropriately designed transport equipment.