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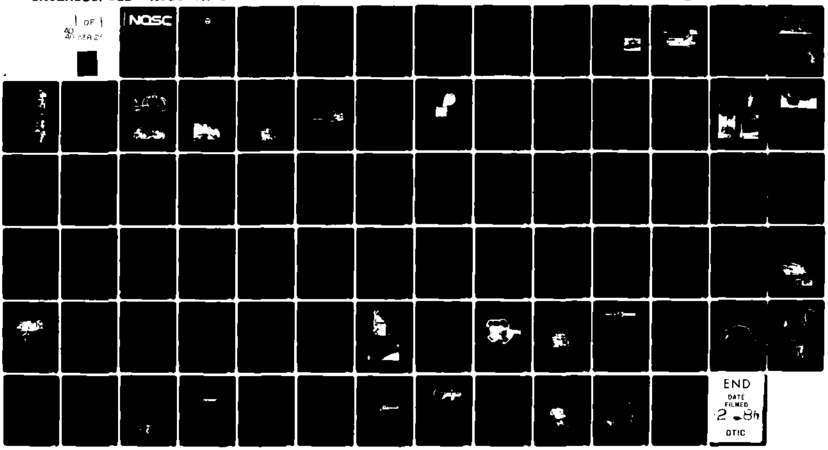

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Technical Report 553

WORK SYSTEMS PACKAGE/PONTOON IMPLACEMENT VEHICLE OPERATIONAL TESTING AT SAN CLEMENTE ISLAND, 1979

Demonstration of a technology for remotely controlled deep-water recovery of objects up to 5 tons from depths to 20,000 ft

RL Wernli

6 June 1980

Final Report for Period October 1978-September 1979

Prepared for
NAVAL SEA SYSTEMS COMMAND
NAVSEA 05R2

Approved for public release; distribution unlimited

NAVAL OCEAN SYSTEMS CENTER
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AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

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This report covers work from October 1978 through September 1979.

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METRIC CONVERSION

To convert from	to	Multiply by
foot (ft)	metre (m)	3.048×10^{-1}
pound (lb avoirdupois)	kilogram (kg)	4.536×10^{-1}
ton (short, 2,000 lb)	kilogram (kg)	9.072×10^{2}
pounds per square inch (psi)	pascal (Pa)	6.895×10^{3}

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Work Systems Package, mated to the Pontoon Implacement Vehicle, recently completed extensive in-water testing to depths of 95 feet at the Navy's San Clemente Island test facility, in order to investigate techniques for attaching, rigging, and recovering objects using a remotely controlled vehicle/work system. Objects ranged from heavy steel structures to aircraft and components. Lifting methods included use of vehicle thrusters, variable ballast, and a remotely controlled module with a 10 000-pound lift capability. Valuable information concerning recovery technology was acquired during the mission, a highlight of which was the successful rigging

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and lift of a 10 000-pound F4 Phantom jet fuselage. Excellent data and photographic documentation were obtained. A total of 58 hours of in-water testing was performed in 14 dives.

OBJECTIVE

Investigate various techniques for attaching, rigging, and recovering objects from the seafloor using a remotely controlled vehicle/work system.

RESULTS

The Work Systems Package (WSP) recently completed extensive in-water testing at the Navy's San Clemente Island (SCI) test facility. The WSP was mated to the Navy's Pontoon Implacement Vehicle (PIV) and transferred to SCI for testing on 17 July 1979. Using a crane barge as a work platform, testing was performed in depths to 95 feet in the Naval Ordnance Test Station (NOTS) Pier area. Recovery objects ranged from heavy steel structures to aircraft and components. Methods of lifting included use of the vehicle thrusters and/or variable ballast or a remotely controlled lift module with a 10,000-pound lift capability.

Fourteen dives were made with an accumulated total of 58 hours, 13 minutes of in-water time. The operating experience gained with the vehicle/work system and the substantial amount of photographic documentation acquired have greatly enhanced the success of this test series and demonstrated simple and reliable techniques that can ensure recovery through the use of remote systems. The following operations were successfully completed:

Slinging and lift of a 10,000-pound F4 aircraft fuselage to the ocean surface

Claw attachment to and recovery of a jet engine

Rigging and recovery of a large steel object.

In addition, techniques were developed which successfully demonstrated the system's capability to perform the following:

Rigging of objects (installation of lift lines, snaphooks, etc)

Performance of midwater maneuvering, docking, rigging, and recovery operations

Successful installation of lift slings on an intact aircraft

Object recovery using the vehicle variable ballast and thrust as the lift force

Remote implacement and deployment of a lift module which can be controlled by the work system or a microprocessor to generate a 10,000-pound lift force

Object recovery using the lift module while under diver control

Installation of toggle-bolt lift points through heavy steel plate

Successful manipulative operations using a TV system providing a reduced image update rate (ie, update of TV picture at a slower rate to allow multiple use of same coax by other TV systems).

Although these tests were performed in shallow water where they could be properly documented, the successful completion of the work-related tasks of the system at depths to 20,000 feet would not be significantly different since they are basically depth independent.

RECOMMENDATIONS

Develop cable dynamics models and gather further at-sea data to verify the programs.

Integrate fiber optics, multiple television, and other viewing techniques to allow viewing of the work area and the area near the work vehicle.

Develop an undersea work/recovery manipulator.

Develop an ensemble of attachment and rigging devices for use by remotely operated systems.

Develop microprocessor-controlled gas-generation lift modules for object recovery.

CONTENTS

ILLUSTRATIONS

INTRODUCTION

During fiscal year 1979, a multi-laboratory working group was formed to examine the alternative techniques for recovery operations in the deep ocean. The group is comprised of representatives from the Naval Ocean Systems Center (NOSC), the Civil Engineering Laboratory (CEL), the Naval Coastal Systems Center (NCSC), Battelle Memorial Institute (BMI), and the Office of the Supervisor of Salvage. Under the Deep Ocean Technology Program (DOT) managed by the Naval Sea Systems Command (NAVSEA 05R2), the project has as its ultimate aim the specification, fabrication, and documentation of representative equipment, systems, and techniques which will form a technology base for the recovery of objects up to 5 tons from depths to 20,000 feet.

Increasing exploration and exploitation of the seafloor for raw materials, food, and defense have resulted in the proliferation of special-purpose ships and underwater vehicles. It is inevitable that accidents will occur resulting in loss of equipment in deep-ocean depths. For reasons of national value, intelligence, or science, there is a need for salvage and recovery operations. In addition to its own interests, the Navy has been tasked to support commercial United States activities in the open ocean. Although this responsibility is aimed at saving lives, implicit in the instruction is the recovery of valued material.

The purpose of this project is to review the state of the art in the applicable technologies and to develop a technology base to provide the Navy with the capability to develop systems for recovering items of significant size (aircraft, ordnance) from any ocean depth. Technology developed through the Navy's Deep Ocean Technology (DOT) Program, the Large Object Salvage System (LOSS) Program, and the Extended Salvage Depth Capability (ESDC) Program would be directly integrated.

Through extensive tradeoff studies an early concept of such a recovery system was established. It was decided that two systems currently exist which closely meet the requirements for work capability, size, and thrust capability of that concept, the Work Systems Package (WSP) and the Pontoon Implacement Vehicle (PIV).

The Work Systems Package (Figure 1) was choosen as a representative system to demonstrate work capabilities required for deep water recovery and work operations. The WSP was developed and fabricated under the Navy's Deep Ocean Technology Program and is designed to provide a versatile work capability to depths of 20,000 feet. The WSP is a group of manipulator arms and tools integrated into a modular package that will provide a heavy-duty work capability when mounted as a unit on unmanned cable-controlled submersible vehicles, as well as on manned vehicles. In addition, it can be positioned and controlled by divers or operated independently from a surface support ship for operations at shallow depths without the need for a submersible. The system was designed to accomplish a complete work task on the ocean floor without the necessity of resurfacing for tool interchange. Basic components of the work package include two simple outer manipulator arms, without elbow functions, that act as "grabbers" or restraining/holding arms to steady the vehicle or to hold small work pieces. A centrally located seven-function manipulator arm can select, interchange, and operate a variety of hydraulically-powered, explosively-actuated, or electrically-actuated tools. Included in the tool storage box are tools to perform cable cutting, synthetic line cutting, nut torquing, jacking, prying, wire brushing, sawing, grinding, drilling, chipping, and stud driving. An electrically-driven hydraulic pump unit supplies the power to a majority of the tools. Electric power is supplied from a self-contained battery package. Control of all operations and functions is provided through a multiplexed telemetry circuit from the vehicle. Pressure insensitive electronic circuits and pressure compensated hydraulic components allow all systems to operate at full ambient pressure.

The Pontoon Implacement Vehicle (Figure 2) was chosen as the mounting platform for the WSP. The PIV was developed as a part of the Large Object Salvage System (LOSS) at the Naval Coastal Systems Center, Panama City, Florida. The PIV is a cable-controlled, highly maneuverable, and precisely controllable vehicle. The PIV is powered through a system of five variable-speed thrusters, providing three-dimensional motion. A variable ballast system, carrying a load of sea water up to 2,000 pounds, can be used in conjunction with thrusters to provide the lifting force. A television camera and light source are mounted on each of two pan and tilt units to assist in flying and positioning of the vehicle for salvage or recovery operations.

This report summarizes the results obtained during the at-sea testing of the WSP/PIV system. A description of the test objects, attachments, rigging methods, and lift methods is provided. Test logs and detailed hardware descriptions are provided in the appendices.

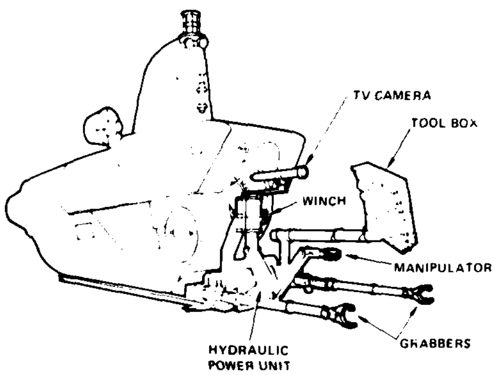

Figure 1. WSP on Alvin.

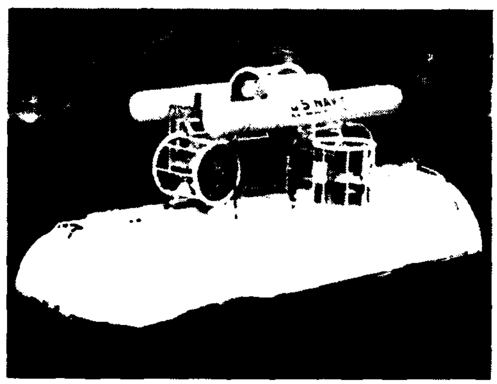

Figure 2. Pontoon Implacement Vehicle. (LRO 47059-3)

BACKGROUND

The Work System Package (WSP) was mated with the Pontoon Implacement Vehicle (PIV) (Figure 3) and transferred to San Clemente Island (SCI) for testing on 17 July 1979. SCI had been chosen as the test site because of the clarity and depth of the water and the protection provided by the NOTS Pier area (Figure 4). Operations were conducted off the YD197, a NOSC crane barge (Figure 5). This provided WSP personnel with adequate deck space and support facilities along with a crane capable of launching and recovering the approximately 28,000 pound vehicle. The vehicle was released from the YD197 crane by divers once it was in the water.

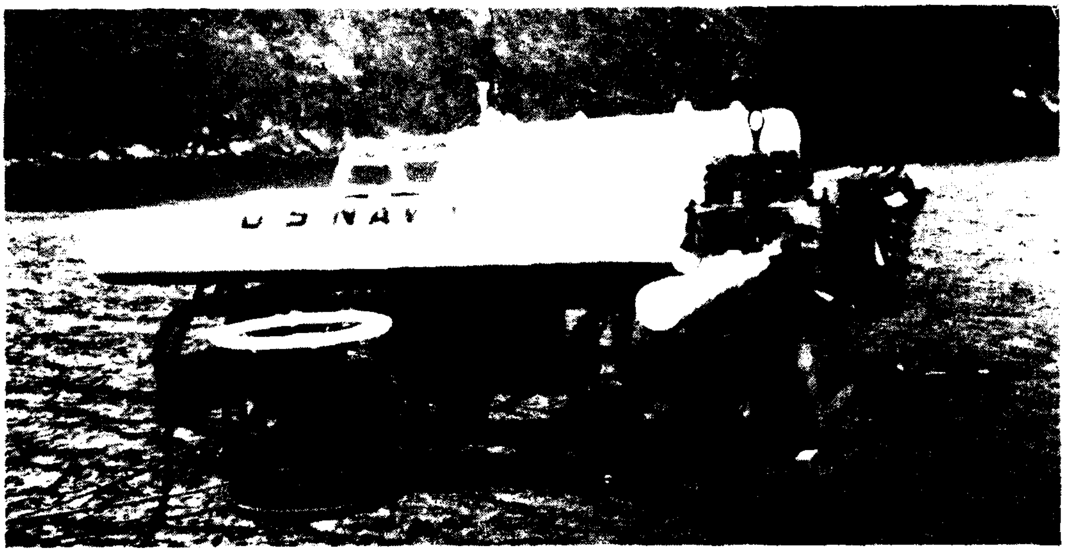

Figure 3. Work System Package mated with Pontoon Implacement Vehicle. (LRO 3544-8-79B)

The purpose of the test was to investigate or develop applicable recovery techniques to be used in conjunction with a remotely controlled vehicle/work system, the WSP/PIV. Results from the testing will be used in the formulation of a technology base which will provide the Navy with the capability to develop future systems to perform deep ocean recovery operations.

An operational depth of 65-95 feet was chosen. Although the lighting and cable dynamics for the system at this depth could not duplicate those of a 20,000 foot system, it was determined more important to acquire proper test documentation. Through the use of scuba divers, both observation and photographic documentation could be maximized, while the system performed the complex rigging and recovery operations. In addition to the still and motion picture coverage provided by the divers (Figure 6), the WSP/PIV cameras were connected to a video tape system for backup documentation, and a test log was kept which details each step at the operation and all problems encountered (Appendices A and B).

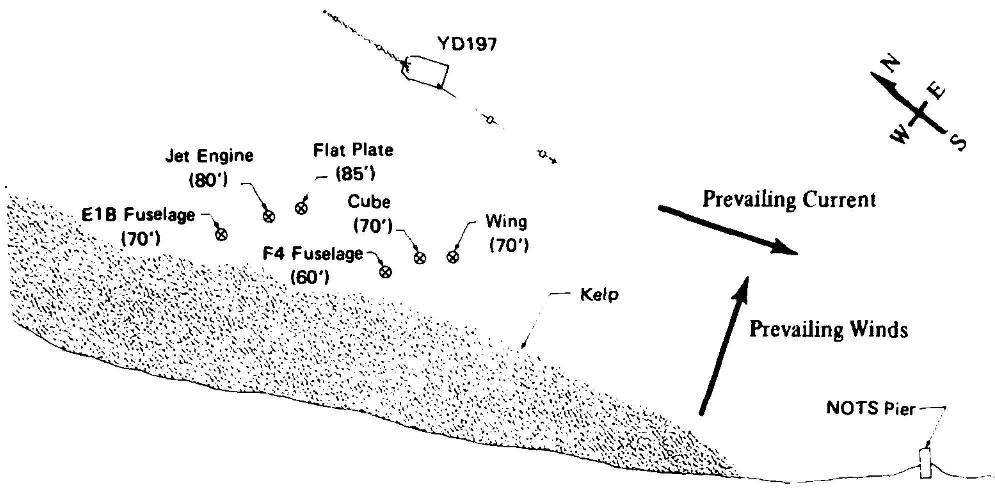

Figure 4. SCI mooring/target location chart.

Prior to each dive, meetings were held to cover the operation planned for the day. The WSP/PIV was operated during the six-week testing period by two of three task team members chosen for this task. The WSP and PIV control consoles were installed side-by-side in the control van to allow close communication between the operators. The WSP functions and TV cameras were controlled by the WSP operator while giving direction to the PIV pilot during in-water flight. Once the desired dive area was reached by the vehicle, it was thrust to the bottom and positioned for the test sequence of the day. The vehicle, which is slightly buoyant, was then held on the bottom using its vertical thrusters.The WSP/PIV operators were then able to decide the required course of action and begin the task.

TEST OBJECTS

Trade off studies were conducted during FY-79 to determine the most feasible method of rigging and lifting objects from the ocean bottom. For testing purposes test objects were chosen to reflect the general characteristics of classes of objects which might require recovery. The generic objects chosen were:

a. Flat Plate — Approximately 8 feet x 8 feet, 1/2-inch thick steel. This provided a heavy, thick, large drag object capable of accepting simple attachments.

b. Large Appendaged Object — A larger, heavier object that would allow use of both simple or complex methods of attaching/rigging on or off the bottom was desired. The "old WSP test fixture" was used for this object. It is approximately a 5 feet x 7 feet open steel cube. Approximate weight is 2,400 pounds (Figure 7).

c. Jet engine (Figure 8).

d. Wing section (Figure 9).

e. Aircraft — F4 and E1B (Figures 9 and 10).

The aircraft components provided structures with thin skins upon which multiple methods of lift could be attempted. They also are large, high drag objects with considerable entrained water.

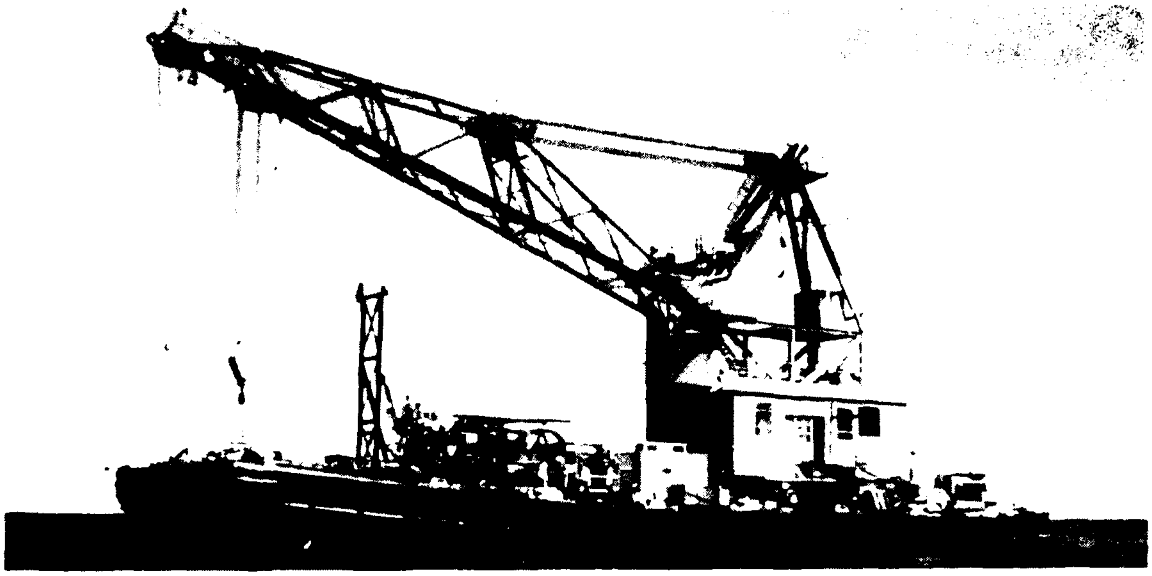

Figure 5. YD197 with WSP/PIV on deck.
(LRO 4305-9-79B)

Figure 6. WSP/PIV with divers taking photographic coverage of lift module (bottom left) being rigged to the aircraft (center) prior to recovery. (LRO 4308-9-79B)

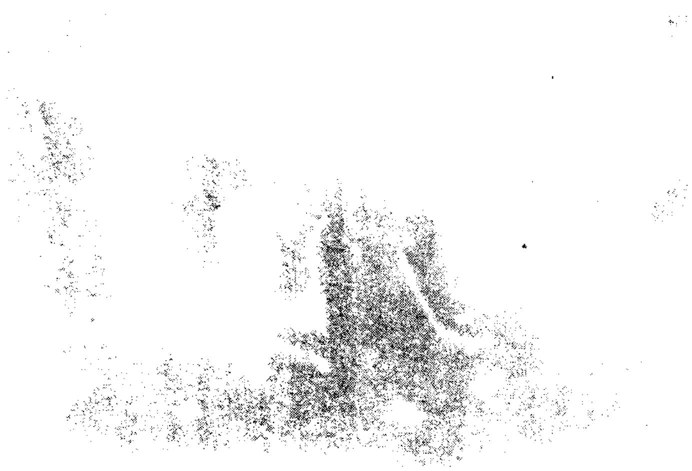

Figure 7. Test fixture. (LRO 4122-9-79)

Figure 8. Jet engine. (LRO 4133-9-79)

Figure 9. E1B and wing section. (LRO 3123-79A)

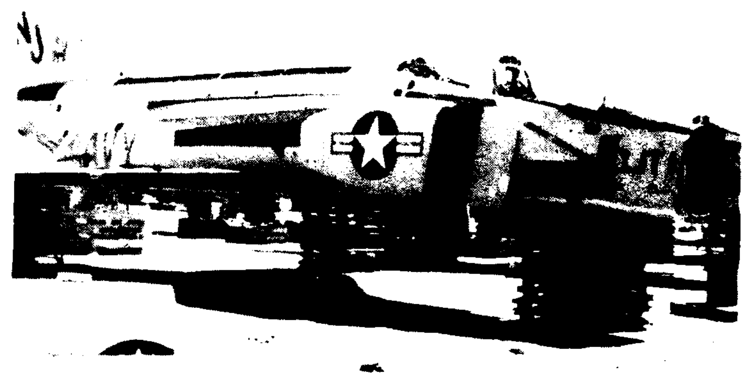

Figure 10. F4 (LRO 3143-79A)

ATTACHMENT DEVICES

Studies were conducted to determine the most applicable attachment methods within today's technology for use during SCI testing. It was assumed that the object had been located, marked, and photographed and that the recovery team knew, as accurately as possible, the condition of the object to be recovered to aid in the choice of attachments. The following paragraphs detail the types of attachments chosen. The applicable appendix for each attachment explains in more detail the design, operational scenarios, and observations made during SCI testing.

Claw — The claw assembly (Figure 11) provides grasping similar to that used for torpedo recovery and was used during SCI testing to provide an attachment point for the lifting of a jet engine. This test was designed to provide data on attachment/lift feasability for aircraft components under 2,000 pounds. The claw assembly was borrowed from the Submarine Development Group 1 for use in the SCI testing.

The claw assembly, which can't be reopened underwater after it has been tripped, works on an ice-tong effect in that when the trip lever is activated, the claw closes encompassing the target in its grasp. Minor modifications to the claw assembly were required and are detailed in Appendix C.

Mating of the vehicle and claw is accomplished by raising the vehicle above the barge deck and then drawing the claw into the crossbar of the PIV and hydraulically activating the locking shaft to secure the claw, in the open position, to the vehicle. The trip mechanism hook is positioned on the WSP toolbox for acquisition by the manipulator. The vehicle is launched and proceeds to the target. Once at the recovery site, the vehicle hovers above the target and then slowly descends until the claw encompasses the target. The manipulator acquires the trip line and pulls to activate closing of the claw. Lift of the object is achieved through use of the vehicle thrusters, decreasing the 2,000-pound variable ballast or a combination of both.

A successful lift of a jet engine was conducted using the claw assembly as the attachment point. Deficiencies with the original claw design were experienced but did not severely hamper operations.

Sling — The lift sling emplacement device (Figure 12) was developed to provide a lift method for objects, such as aircraft fuselages, which do not readily lend themselves to the installation of attachment points. The most desirable method of rigging this type of object is through the use of rope, cable, or strap type lifting harnesses to provide a choke hold on the object to be recovered. Difficulty arises in this task when the object to be recovered is buried in mud or sand; the lift sling assembly was developed to alleviate this problem.

The lift sling assembly was developed to conform to the following characteristics:

a. Ability to pass a 6-inch-wide x 1/8-inch-thick synthetic sling at a minimum rate of six inches per minute around an eight-foot diameter object which is resting half buried in a mud bottom.

b. Operable by the Work Systems Package with jetting water provided by the variable ballast pump of the PIV.

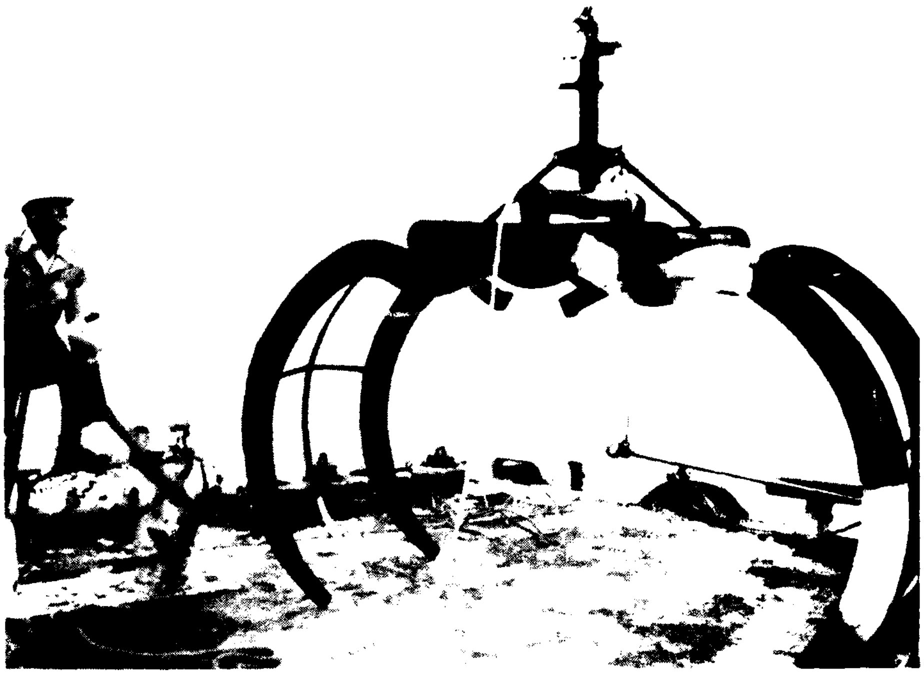

Figure 11. Claw assembly (approximately 5-foot wide opening).
(LRO 3430-8-79B)

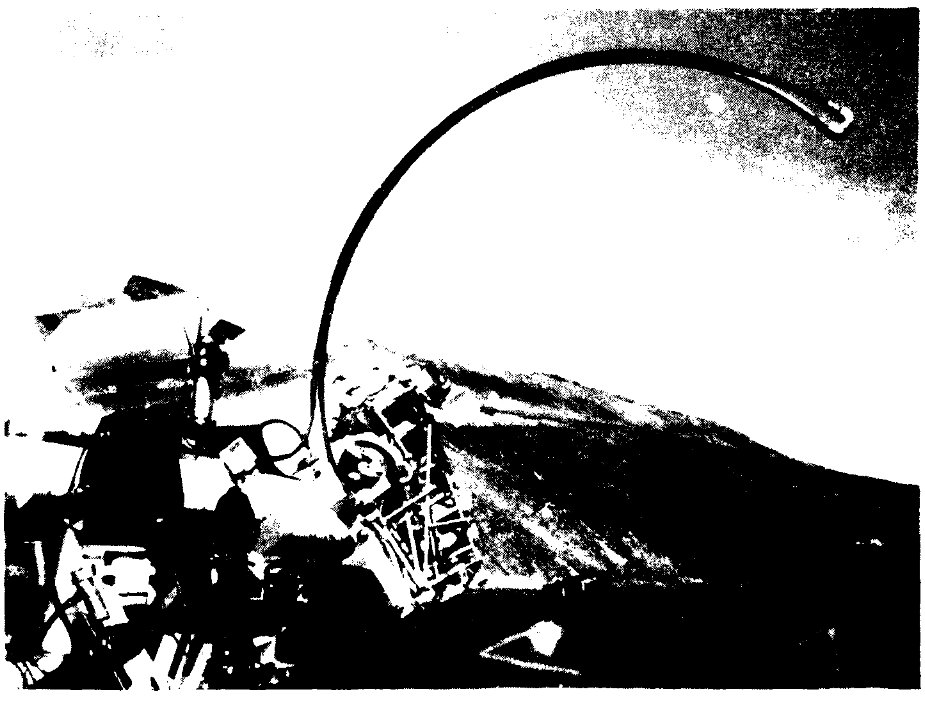

Figure 12. Lift sling emplacement device (15 3/4 feet long, 10-foot diameter semicircle).
(LRO 4271-9-79B)

e. Operable to a depth of 850 feet.

The sling assembly is constructed with curved steel tubing which is shaped in a ten-foot diameter semicircle. It is mounted on the WSP toolbox and removed through the use of the starboard grabber. After the grabber positions the assembly, the manipulator can force the sling under the aircraft. The sling is guided by three rollers located in the mount held by the grabber. The slinging device is equipped with a jetting nozzle which helps clean a path for the sling during insertion through a sand or mud bottom. After complete insertion, a synthetic line, which is attached to the near side of the sling, is taken over the aircraft and passed through a loop in the end of the sling. The snap hook on the synthetic line can then be attached to the main lift point, thus providing a "choke" hold on the target.

A successful lift of an F-4 aircraft was conducted using two sling assemblies connected to a common lift point. The lift module was used to provide the lifting force required. For details of testing refer to Appendix F.

Net (Basket) — Development of the net assembly (Figure 13) arose from the need to provide surface stabilization of a recovered object for a minimum of 8 hours. This will allow the salvors a sufficient time frame in which to secure the recovered object for towing or lifting aboard a salvage vessel. The net assembly provides a means of enclosing and holding an object without the use of conventional attachments. Should any primary attachments be used the net would provide a backup to prevent loss of the encapsulated object should the primary attachments fail.

The advantages of this system include:

a. The adaptability of nets to any size or weight object.

b. Use of the ocean bottom as a table for the net during object placement.

c. Ease of transition from the subsurface operations phase to the surface stabilization mode.

d. Light weight and compact for transporting to the recovery site.

e. Low capital cost.

Figure 13. Net. (LRO 4297-9-79)

The net assembly in its stowed position measures 4 feet wide by 20 feet long and in its deployed state forms a 20-foot square. For transit to the recovery area the net assembly is secured, in the stored condition, to the underside of the PIV. Once at the recovery site the net is released by the hydraulically actuated shaft/hooks securing it in position. The PIV is then backed off from its position over the net while faking out the fill hose. The net assembly is deployed by filling the side members of the net with sea water causing the members to become rigid. The recovered object can then be placed in the net for lifting to the surface.

Due to limited testing time only one test was conducted on the net assembly. During this test only partial deployment of the net was achieved. Minor design modifications would be required prior to use during recovery operations. Refer to Appendix G for further information.

Rigging Module — The Rigging Module (RM), see Figure 14, was developed as a load equalization system to provide a single lift point for the recovery of objects with unbalanced weight distributions. When lifting items of this configuration, the loading factor on one or two lift points can become excessive and create a hazardous lift condition.

The Rigging Module consists of a framework, encasing buoyancy pods, equipped with a garland ring on top to function as a lift point. Four attachment arms extend from the underside of the frame. These attachment arms are configured with a slip clutch assembly which adjusts during lift to provide for equal distribution of the recovered object's weight. The slip clutch resistance is adjustable on each arm and must be set prior to launch. Each arm is equipped with lines and hooks for attachment to a pre-installed or existing lift point. As the lift is begun, the attachment arm on the heavy side of the recovery object will reach its predetermined load limit and begin to pay out line. Depending upon the weight distribution on the object, three of the four slip clutch assemblies may have to slip to distribute the weight of the load on all four arms equally. At this point lift can be achieved.

The Rigging Module was used for attachment to the steel test fixture and subsequent lift using PIV thruster power. The slip clutch assemblies appeared to operate properly. Further details and a complete description of Figure 14 are contained in Appendix E.

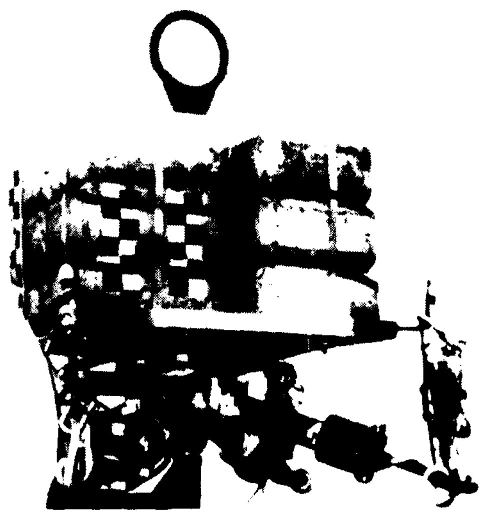

Figure 14. Rigging Module.
(LRO 3485-8-79)

Toggle — The Toggle Bolt padeye (Figure 15) was developed as a method of quickly and easily installing lifting points for sea-floor recovery operations. Current methods of recovering large, plate-like structures consist of using slings, grapples, or nets to capture the object to be recovered. These techniques are cumbersome, slow and frequently ineffective.

The primary advantages of the toggle bolt padeye include easy installation, small size, and high lifting strength with a small through-hole requirement. The prototype has been tested to 4,700 pounds with a through-hole of 3/4-inch diameter. This is achieved primarily through the unique eccentric configuration of the unit. A relatively large load bearing area is available through the grip plug configuration. The toggle bolt is easily installed by the WSP manipulator into a predrilled hole and once locked the entire assembly rotates as a unit and the bearing surface is preserved for all orientations of the eye.

A total of two toggle bolt padeyes were successfully inserted and locked into position on the steel plate. Due to delays in diver support and approaching darkness, a lift test of the object was not conducted. Appendix H details observations made during SCI testing.

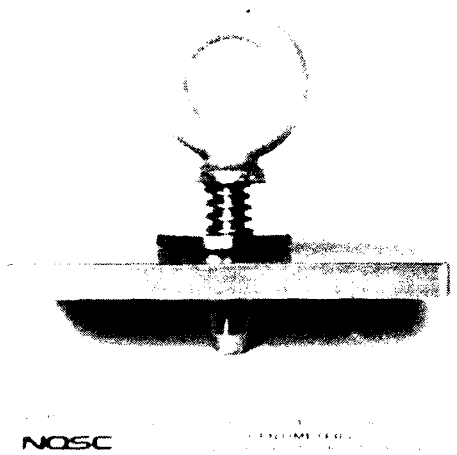

Figure 15. Toggle Bolt padeye.
(LRO 2686-6 79B)

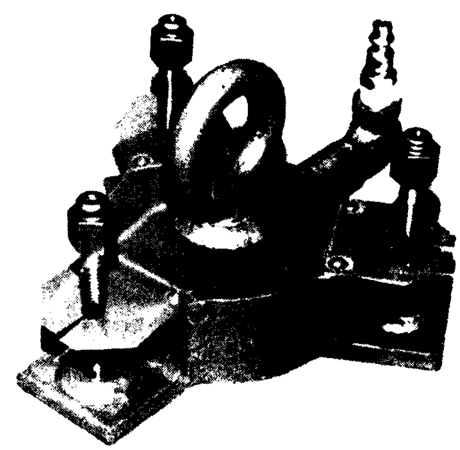

Figure 16. Drill-Tap-Bolt padeye.

Drill-Tap-Bolt Padeye — The Drill-Tap-Bolt (DTB) padeye (Figure 16) was developed as an improved method of providing an attachment point for the installation of lift lines on an object which has an external structure or framework of sufficient thickness and strength for drilling, threading and bolting. The installation of an attachment bolt under water using existing technology is a difficult task. The manipulator operator must insert a drill bit into the manipulator-held power tool, move to the object, and drill the required hole(s). Next he must move back to the toolbox, remove the drill bit, insert a tap in the tool, move back to the work site and tap the hole without jamming or breaking the tap in the drilled hole. The tap must then be backed out, the tool moved back to the toolbox, the tap removed, and a bolt-running attachment placed on the tool. Finally, a bolt must be installed in the bolt-running attachment and moved back to the work site where the bolt is placed in the hole and torqued without jamming the threads, while the piece to be bolted to the object is held in place. The use of the DTB padeye will provide a time-effective method of accomplishing this task with only two trips to the toolbox required (vice three). Also, improved operator control over problems such as the breaking of taps during installation or removal, holding of the padeye during bolt insertion, and alignment/installation of the attachment bolt(s) is provided by the integrated design of the DTB padeye.

The DTB padeye was developed to conform to the following characteristics:

a. A pull strength of 1,000 pounds (minimum) in 1-inch thick A-36 Steel.

b. Operable by the Work Systems Package using the impact wrench tool for insertion of the drill-tap-bolts.

c. To be held in place against the object to be recovered by means of a suction device integral to the padeye. The suction pressure was to be provided by the variable ballast pump of the WSP's host vehicle.

d. Operable to depths up to 20,000 feet.

Due to required completion of higher priority tests, this unit was not tested in the water at SCI. An on-board test to check the suction force created was conducted and results are detailed in Appendix I.

LIFT METHODS

After rigging of the test objects for a single-point lift the object was secured for transport to the surface. The PIV through the use of its thrusters alone or in conjunction with the Variable Ballast system was determined to be the most applicable lift method for small to medium test objects. A Lift Module, developed by NOSC, Hawaii, was intended to demonstrate the feasibility of utilizing a fixed displacement lift bag with a self-contained gas source for the lift of objects weighing up to 5 tons.

Pontoon Implacement Vehicle (PIV) — Use of the vehicle to raise objects with an inwater weight of 3,600 pounds can be accomplished by using the vertical thrusters to provide the lift force (800 lbs each) and in cases where the weight of the object prohibits this, the variable ballast can be used to provide an additional 2,000 pounds of lift capability. During SCI testing the variable ballast was used to assist in raising the jet engine and test box in conjunction with the PIV thrusters. Two methods of raising an object using thruster augmentation are: manual control of the ascent rate, or automatic control using the automatic depth/altitude control.

After rigging the object to be recovered for a single-point lift, an attachment line from the PIV is secured. If the variable ballast is to be used to augment the lift force of the vehicle thrusters, all ballast is dumped at this point. The ballast pump will automatically shut off with approximately 50 pounds of ballast remaining. Lift can be achieved through manual control of the thrusters or by engaging the automatic depth/altitude controls. The automatic depth/altitude controls provide fine control over the vehicle ascent rate.

Lift Module (LM) —The Lift Module (Figure 17) was developed to demonstrate the feasibility of utilizing a fixed displacement lift bag with a self-contained gas source as a means of transporting an object from the ocean bottom to the surface. This method eliminates the unreasonably high power requirements which would be required to lift a 10,000-pound object using vehicle thruster power.

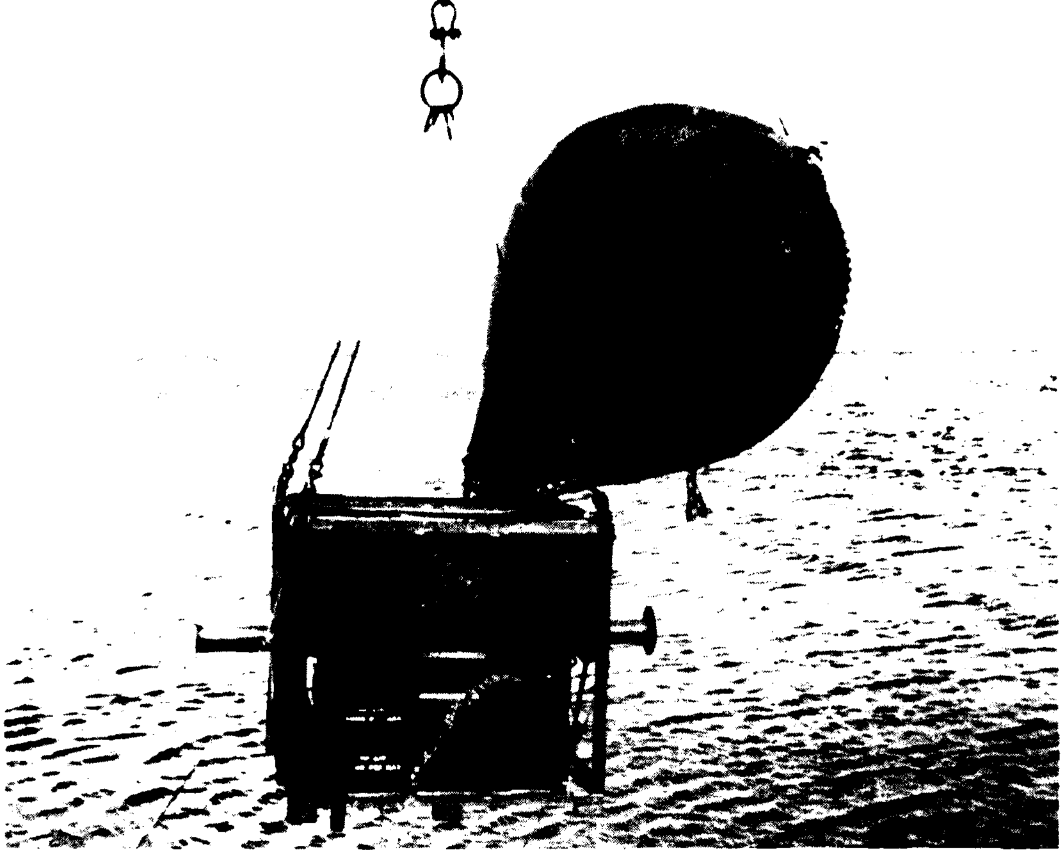

Figure 17. Lift Module being recovered after test.
(LRO 4232-9-79)

The Lift Module used at SCI is a submersible system with the lifting force provided by a 150-cubic foot, air filled, fixed displacement KEVLAR lift bag*. Initially, the lift bag is pumped full of water by a hydraulically driven pump which is under WSP control thus converting it into a "rigid pontoon." This constant bag volume is maintained by a relief valve which keeps the internal bag pressure at 5 to 10 psi over ambient pressure. Buoyancy can be varied by forcing ballast water or air into or out of the lift bag while still under WSP control. When the lift bag buoyancy is sufficient to achieve lift off, ascent is controlled by a microprocessor unit aboard the Lift Module. Control over the ascent rate is required to ensure that the dynamic load is maintained within 10 percent of the static load, and so the venting capacity of the relief valve is not exceeded.

When the Lift Module/Object approaches the surface, the lift bag will break the surface leaving the module and object suspended beneath the surface for salvage recovery operations. The Lift Module is described in more detail in Appendix D.

*It is anticipated that the lift force in a 20,000-foot design would be provided by a hydrogen gas generator.

TEST SUMMARY

A summary of the primary daily operations is included here for reference. It is a good indication of the types of problems and delays encountered during at-sea testing of newly developed R&D equipment. A detailed daily log of the testing is included in Appendix A.

WEEK 1

Sunday, 7/15/79	YD197 Crane Barge taken under tow for transit to SCI.
Monday, 7/16/79	YD197 arrives SCI at 1440, 6 hours overdue. Vehicle inspected and secured from transit.
Tuesday, 7/17/79	Survey dives for locating of targets and clearing of kelp completed. Vehicle prepared for next day's dive.
Wednesday, 7/18/79	Dive on jet engine and test fixture conducted. Dive aborted due to vehicle thruster problems. Time in water: 3 hours, 10 minutes.
Thursday, 7/19/79	Required to clear range for Tomahawk shot. Performed maintenance for remainder of day.
Friday, 7/20/79	Test conducted. Claw used to capture jet engine. Time in water: 4 hours, 3 minutes.

WEEK 2

Monday, 7/23/79	Maintenance/Repairs performed for next dive.
Tuesday, 7/24/79	Maintenance/Repairs continued.
Wednesday, 7/25/79	Test conducted. Rigging Module to test fixture attachment attempted. Poor visibility and lack of time force postponement. Time in water: 2 hours, 30 minutes.
Thursday, 7/26/79	Test conducted. Rigging module attached and rigged to test fixture. Time in water: 5 hours, 47 minutes.
Friday, 7/27/79	Test conducted. Vehicle secures to rigging module and test fixture lift conducted. Time in water: 1 hour, 41 minutes.

WEEK 3

Monday, 7/30/79	YD197 generator failure. PWC support not available for repair.
Tuesday, 7/31/79	Maintenance performed while waiting for PWC transfer of replacement generator. Slinging devices tested successfully onboard YD197.
Wednesday, 8/1/79	Test conducted. Installation of slinging device on F4 conducted. Time in water: 5 hours, 15 minutes.

Thursday, 8/2/79	Test conducted. Umbilical cable blowout forces abort of dive. Time in water: 1 hour, 8 minutes.
Friday, 8/3/79	Maintenance/Repairs on vehicle. Crane Barge not available for cable transfer.
	WEEK 4
Monday, 8/6/79	Maintenance/Repairs on vehicle. Crane Barge still not available for cable transfer.
Tuesday, 8/7/79	Crane Barge arrives for cable transfer. Vehicle operating at 1730.
Wednesday, 8/8/79	Test conducted. Vehicle blew 440 connectors from electronics bottle, dive aborted. Time in water: 1 hour, 15 minutes. Lift Module wet tested by off loading using YD197 crane.
Thursday, 8/9/79	Rebuild electronics bottle. Lift Module readied for test using YD197 crane for off loading and dive boats for transit of module to jet engine for lift.
Friday, 8/10/79	Rebuild of electronics bottle continues. Unable to conduct Lift Module test due to loss of diver and crane operator support.
	WEEK 5
Monday, 8/13/79	Rebuild of electronics bottle completed. Diver-operated Lift Module test on jet engine conducted. Jet engine recovered.
Tuesday, 8/14/79	Required to clear range for Tomahawk shot. Performed maintenance for remainder of day. Electronics bottle installed and vehicle operational at 1630.
Wednesday, 8/15/79	Test conducted. Slinging device installed on F4 for lift. Time in water: 4 hours, 13 minutes.
Thursday, 8/16/79	Test conducted. Rigging of slinging device completed. Time in water: 4 hours, 35 minutes.
Friday, 8/17/79	No crane operator support. Dive cancelled, maintenance performed.
	WEEK 6
Monday, 8/20/79	Test conducted. Lift Module positioned near F4 and prepared for lift. Time in water: 6 hours, 14 minutes.
Tuesday, 8/21/79	Lift Module raises F4 aircraft. Time in water: 6 hours, 45 minutes.
Wednesday, 8/22/79	Test conducted to obtain additional film coverage of lift module raising F4. Suspended due to loss of diver support. Test conducted installing toggle bolt assembly on flat plate. Time in water: 7 hours, 5 minutes.

Thursday, 8/23/79	Perform vehicle maintenance/repairs. Rig net for next day's dive. Recovered Lift Module.
Friday, 8/24/79	Test conducted. Recovery net deployed and E1B cutting operations attempted. System secured for transit to San Diego. Time in water: 4 hours, 15 minutes.
	WEEK 7
Monday, 8/27/79	YD197 taken under tow for transit to San Diego.

TEST RESULTS

During the 30 days of testing just summarized, 14 dives were made with the vehicle which accumulated a total of 58 hours, 13 minutes of in-water time. Of the remaining 16 days, seven were required for routine maintenance or repair while nine were lost for various reasons (Figure 18). This time breakdown is typical of what can be expected when testing newly developed or integrated equipment/systems at sea for the first time. The operating experience gained with the vehicle/work system and the substantial amount of photographic documentation acquired have greatly enhanced the success of this test series. Appendix B provides a detailed listing of system problems enountered during testing.

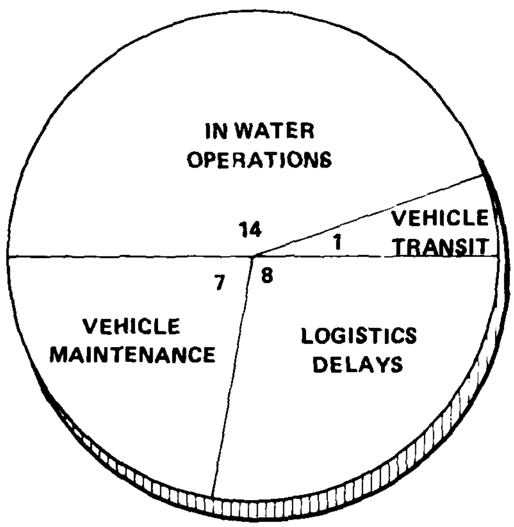

Figure 18. SCI testing time breakdown (days).

The basic approach to these tests was from an engineering standpoint. Given a recovery task, an engineering approach could be made to the task which would result in the development of simple and reliable techniques to ensure a successful recovery through the use of remote systems. Based on this approach, the following objects were successfully rigged for recovery and lifted to the ocean surface using the recovery techniques developed and explained in previous sections:

— Slinging and lift of an F4 aircraft (Figure 19).

— Claw attachment to and recovery of a jet engine (Figure 20).

— Rigging and recovery of a large steel object (Figure 21).

In addition, techniques were developed which successfully demonstrated the system's capability to perform the following:

— Rigging of objects (installation of lift lines, snaphooks, etc.) (Figure 22).

— Performance of midwater maneuvering, docking, rigging and recovery operations.

— Successful installation of lift slings on an intact aircraft.

— Object recovery using the vehicle variable ballast and thrust as the lift force.

— Remote implacement and deployment of a lift module which can be controlled by the work system or a microprocessor to generate a 10,000-pound lift force (Figure 23).

— Object recovery using the Lift Module while under diver control.

— Installation of "toggle bolt" lift points through heavy steel plate.

— Successful manipulative operations while using a TV system providing a reduced image-update rate (ie, update of TV picture at a slower rate to allow multiple use of same coax by other TV systems).

The ability to perform the previous tasks through the use of remote systems, while the operator is topside in a comfortable environment, validates the use of an engineering approach to recovery tasks. By identifying classes of objects to be recovered, and designing recovery techniques and devices for those classes of objects, a basic inventory of hardware can be established to provide a remote recovery capability. Although these tests were performed in shallow water where they could be properly documented, the successful completion of the work-related tasks of the system at depths to 20,000 feet would not be significantly different since they are basically depth independent. The primary depth dependent requirement would be the need to eliminate cable dynamic forces at the vehicle, which were not of a magnitude to hamper operations due to the shallow water at SCI. Also, operations were conducted under ambient lighting conditions. This entire test series was performed during the first at-sea operations of the WSP/PIV, using newly developed attachment devices and techniques by operators who were new to the system's operational idiosyncrasies. When considering these facts, the reality of what could be accomplished through the development of a technology base which would provide the path to an optimized deep ocean recovery system cannot be overlooked.

Figure 19. F4 recovery.
(LRO 4349-9-79B)

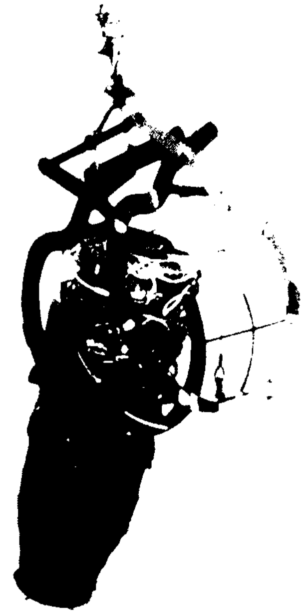

Figure 20. Jet engine recovery.
(LRO 4258-9-79B)

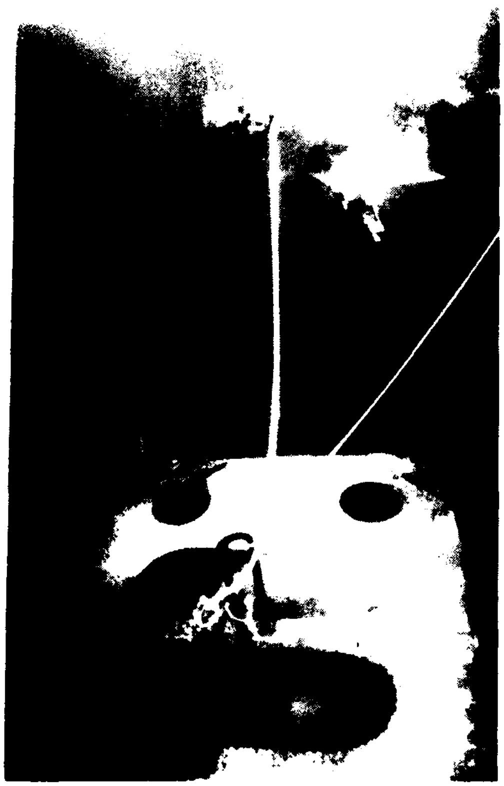

Figure 21. Test fixture recovery.
(LRO 4075-9-79B)

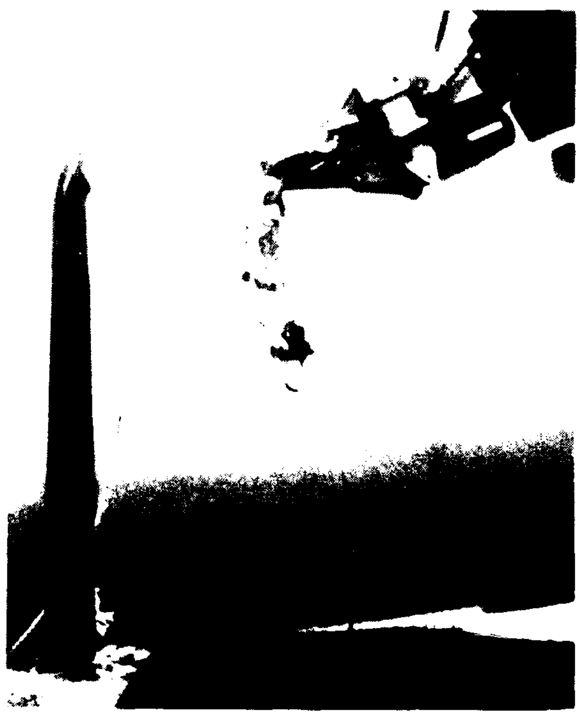

Figure 22. Rigging Module installation.
(LRO 4078-9-79)

Figure 23. Lift Module docking.
(LRO 5640-12-79)

CONCLUSIONS AND RECOMMENDATIONS

At this time, the Navy does not have a routine, cost effective method for recovering objects below diver depths. However, by establishing a proper technology base, methods can be developed which will provide a deep ocean recovery capability to 20,000-foot depths. The testing of the WSP/PIV was a demonstration of such technologies derived from previous programs, and new recovery techniques which were generated specifically for the San Clemente Island (SCI) operations. The ability to successfully develop such recovery techniques through an engineering approach was demonstrated during the SCI testing.

The tests demonstrated the capability of the remotely-controlled system to perform underwater work operations, remote installation and rigging of slings around an aircraft, and the ability to raise the aircraft to the surface using a gas-operated lift module which had been transported to the work site by the vehicle/work system. New techniques for installation of lift points, attachment of snap hooks and rigging lines in a "fail safe" manner, and the successful recovery of a jet engine have expanded the Navy's recovery technology.

The demonstration of the work/recovery capability of the WSP/PIV was the first step in extending this technology to the deep ocean, where successful completion of such work tasks is more dependent on proper system design than on the operating depth. Thus, the greatest challenge is to deliver this system to the working depth; a challenge which has to meet launch, recovery, and the handling of cable dynamics during operations in unfavorable sea states. Concurrent programs have addressed this area, and with the continuation of their state-of-the-art advances, the extension of the Navy's recovery capability to the deep ocean is technically feasible.

However, in the continuing effort to advance the state-of-the-art in deep ocean recovery technology, certain areas lie on or near the critical path and should be addressed with greater emphasis in the near future. A dedicated effort in the following areas will enhance the Navy's quest to obtain a deep ocean work and recovery capability.

Cable Dynamics — The greatest problem with tethered vehicles is the mitigation of the cable dynamics. Cable handling systems have been designed for tethered vehicles, based on parametric studies using advanced computer program models. However, adequate at-sea data has not yet been provided to totally verify the existing computer programs, nor have these programs been advanced to the level of input/output desired. An optimized cable handling system, whether in size, cost, complexity or capability, cannot be designed unless it can be properly modeled; and these models must be accurately validated so their results are not questionable. Without the tools to properly evaluate system concepts, which include the vehicle, cable, and handling systems, the final design may be based on optimism, and not fact. The completion and verification of the present programs is a necessity to complete a proper system design.

Viewing — The state-of-the-art in underwater viewing systems has progressed rapidly in recent years; however, the proper integration of this technology on a system level has not been performed. With remotely controlled systems, if you can't see, you can't expect to perform the work. Technology is available to properly integrate fiber optics, multiple televisions, and other viewing techniques on a system level so that the work area will be properly viewed and the status of all areas around the vehicle system will be known at all times. Future vehicle work systems will not have just the two-man team of the pilot and the manipulator operator, but will have the viewing supervisor, whose job will be to monitor all video transmissions through the use of multiple monitors and provide the operators with the required views. Concurrently, he will monitor all aspects of the system. Through application of bandwidth reduction and transmission sequencing techniques, any required number of TV pictures can be provided to the topside operators. Although this area is presently being studied, an in depth program is required.

Manipulators — Although the technology is available to produce a manipulator to meet the Navy's work/recovery needs, no such manipulator has been designed. A manipulator which balances simplicity of design and operator training with cost, reliability and required work complexity is a necessity. The ability to arrive at 20,000-foot depths to perform a work/recovery operation is totally negated if the manipulator malfunctions or cannot do the job. Reliable methods of remote undersea manipulation must be developed.

Tools/Attachments — Providing the tools to perform work and a method to lift an object does not provide a recovery capability. Work and recovery are separated by the deficient area of attachment design. Without the capability to attach lift points to an object and then rig these multiple points to a single lift point in a "fail safe" manner, successful recoveries cannot be performed. The SCI tests provided the first step in providing such attachment and rigging methods. The continued development and testing of such devices is required. Remote operations are inaccurate and inefficient, and the devices used by such a system must take this into account for successful deployment and operation. The Navy should develop, and have on standby, an ensemble of such devices which can be used by its remotely operated vehicles. In addition, techniques to provide temporary attachment of the vehicle to the target must be developed. Providing manipulators and grabbers will not benefit the operator if the vehicle cannot attach to the work object to provide a stable operating base. Thruster augmentation is not sufficient to allow a system to conduct work operations when it is operating off the ocean bottom. Therefore, devices to allow the grabgers or restraining arms to offset the inaccuracy of thruster station keeping, especially in high currents, must be designed.

Lift Modules/Gas Generation — The SCI operations have shown the feasibility of utilizing microprocessor controlled lift modules for object recovery. The application of microprocessor control to the basic idea of recovery by lift bags will take this concept from diver depth to the deep ocean. However, the extension of these gas generation systems to 20,000-foot depths has not been completed. Prototype systems must be designed, fabricated and tested to assure that all technological problems have been eliminated.

Although proper application or advancement of today's technology is required in all system design areas, most do not lie on the critical path. If a program is generated to develop a deep ocean recovery system, then the previous areas will be critical to that program; however, if the Navy is to succeed in the area of deep ocean work and recovery, these areas must be addressed whether part of an overall program or as single developmental efforts.

This report has been prepared to present an overview of the operations conducted and the technological areas addressed during the SCI tests. Detailed analyses being performed on both the successes and failures at SCI will expand today's technology base and highlight areas of technological deficiency. This will aid in identifying which areas are within the state of the art and which are on the critical path of developing the technology to provide the Navy with a deep ocean recovery capability. It is through programs such as this, where hardware is not merely concepted, but operationally tested, that the technology base for a deep ocean recovery capability is evolving. A systems approach to the application of this state-of-the-art technology combined with advancements in specific technological areas will provide the Navy with the knowledge required to meet its operational goals throughout the world's oceans.

APPENDIX A
WSP/PIV TEST LOG

The following test log provides a daily timetable of the test operations performed at San Clemente Island (SCI) during the period of 15 July 1979 through 27 August 1979. All pertinent test information is included in this log with basic test operation times. The NOSC task team at SCI consisted of:

Robert Wernli — Project Engineer/Diver
Pat Osborne — Electronic Technician
Bob Flood — Mechanical Technician
Ray Musgrave — Range Officer
Ed Tallerino — Diving Supervisor
Roy George — Photography Supervisor/Diver
Chuck Allen — Photographer/Diver
Frank Stitt — Photographer/Diver
John Skadberg — Photographer/Diver
Norm Estabrook — Engineer/Diver
Andy Estabrook — Engineer/Diver
Eric Tibbert — Engineer/Diver
Jim Walton — Engineer/Diver
Charles Gundersen — Engineer/Diver
Jay Stegman — Engineer
Harvey Iwamoto — Engineer

Sunday, 15 Jul

1300	Pacific Towing departed from NOSC, San Diego pier with YD197 crane barge under tow for transit to SCI. The WSP/PIV and all support equipment had been loaded and secured aboard the YD197 during the previous work week.

Monday, 16 Jul

0800	The WSP/PIV task team departed for SCI from Jimsair at Lindbergh Field, San Diego. The charter flight had been scheduled to depart at 0700 but was delayed due to inclement weather.
0845	Task team arrives at SCI.
0900	YD197 was due to arrive at NOTS Pier at 0830. Anticipated arrival time is 1400.
1440	Pacific Towing arrives at NOTS Pier area and YD197 proceeds under its own power for mooring.
1500	Task team arrived aboard YD197 and proceeded to inspect the vehicle and equipment, and secure from transit.
1630	Securec operations.

Tuesday, 17 Jul

0700	Task team arrives at YD197. Pre-operations meeting held to review day's activities.
0900	Dive team starts search for test objects and clearing of kelp in dive areas. All test objects located and marked with buoys.
	Task team conducted inspection of vehicle and prepared for the next day's dive.
1830	Secured operations.

Wednesday, 18 Jul

0700	Task team arrives at YD197.
1145	Predive check completed and vehicle is launched. Begin in-water checkout of WSP/PIV systems. All systems appear operational during on-surface check.
	Vehicle dove to bottom for checkout of automatic depth and altitude controls. Automatic depth controls function satisfactorily. Automatic altitude control malfunctioning. Vehicle functions as if control is reversed. Problem will be investigated later. All other systems operating properly.
1215	Vehicle returned to surface. WSP upper pan and tilt pans to extreme left and does not return. Slipping potentiometer shaft is suspected. Indicator lights, for automatic depth and altitude, on portable control console go out. These problems to be checked after completion of dive.
1230	Main cable handling winch will not function. Unable to determine cause.
1305	Main cable handling winch begins to function. Vehicle is flown to dive sight and cable payed out to 500-600 feet. Weight of cable hampering maneuverability of vehicle. Problem will be addressed after completion of dive. Vehicle dove to bottom (approximately 70 feet) and search conducted for test object. Unable to locate due to sediment and kelp being stirred up. Resurfaced vehicle.
1350	Vehicle repositioned over dive sight and dove to bottom. Lost control of vehicle and it began to move into kelp. Meter on control pannel indicated +500 volts to the forward athwart thruster indicating running at full power. Joy stick on control panel was in neutral position and when moved had no effect. Aborted dive and shut down power to vehicle. Cable winch used to retrieve vehicle.
1445	Vehicle aboard YD197. Notes for the day follow:

- The depth indicator and altitude indicator lights on the portable control console went out but later began working again. The cause is unknown.

- The weight of the cable without additional buoyancy appears to make the system inoperable in the present mooring. Solutions would be to change the moor and use the YD197 to get closer to the test objects to keep the cable length to a minimum, or, add additional buoyancy to the cable which would be a more time consuming process in the long run.
- The failure of the cable winch appears to be an intermittent short in the control cable for the controller.
- The WSP upper pan and tilt failed in the pan mode, sticking entirely to the left positional stop. This appears to be the result of potentiometer slippage which will be corrected.
- Uncontrollable thrusters and high voltage problem was traced by the end of the work day to the control system for the cable reel brake. System appeared to be overloading circuit causing a reduction of the 15-volt reference voltage required to provide feedback to the auto transformers. This problem with the voltage caused the auto transformers to lock themselves wide open whenever that thruster was activated, and when activated very long the circuit breaker would kick out due to the voltage overload. It is anticipated that this unit will be repaired or replaced tomorrow.
- Auto Altitude Failure — System functioned as if connected in reverse, ie, vehicle 10 feet from bottom, auto altitude set for 15 and system would dive to bottom vice raising 5 feet. Determined control set up in tenths (xx.x) vice hundreds (xxx) as on the auto depth control.
- The cable winch level wind begins to lag the wraps after a short time. Unit does not appear to be geared properly.

1830 Secured operations.
Time in water: 3 hours, 10 minutes.

Thursday, 19 Jul

0700 Task team arrives at YD197.

0800 Dive team conducted survey of jet engine target and cut kelp to clear area for vehicle.

Task team performs maintenance/repairs on vehicle.

1030 Task team on shore as requested, by Range Safety Officer, for pending Tomahawk shot.

1400 Task team returns to YD197. Maintenance/repairs on vehicle continued.

1500 Crane Barge arrives for repositioning of YD197 mooring. Upon completion, YD197 is now 50 feet from nearest target and 300 feet from farthest target.

The following is a recap of the day's maintenance/repairs performed:

- WSP upper pan and tilt sticking in the left stop position was caused by seal leakage in the vane actuators. The spare pan and tilt was installed and with proper zeroing of the potentiometers appears to work satisfactorily.
- The thruster voltage problem was repaired through repair of the control system for the cable reel brake.
- The lower PIV TV camera was repositioned to the starboard side of the WSP facing aft to provide greater visibility of the area where the claw will be positioned for retrieval of the jet engine.

1930 All vehicle systems operating satisfactorily. Operations secured.

Friday, 20 Jul

0600 Task team arrives at YD197. Test for day will be to retrieve jet engine using claw.

1000 Vehicle launched with claw attached and proceeds to target area. Variable ballast adjusted prior to launch to compensate for claw weight. Trim in water is good and claw movement while vehicle is in transit is minimal.

1055 Vehicle dove on target but unable to locate as buoy line is cut prematurely.

1244 Buoy line reattached and target sighted with vehicle at altitude of 14 feet. Maneuverability and hovering ability of vehicle with claw attached is excellent. Upper pan and tilt appears to be having problems.

PIV video is good but WSP video is not sharp. Power is shut off to PIV cameras when not in use and WSP video shows marked improvement. Possible cause of problem is grounding signal interference.

1300 Vehicle descends onto jet engine and claw encompasses target. WSP manipulator is used to pull cable, tripping claw to closed position.

Time to acquire cable and trip claw: 45 seconds.

Variable ballast decreased and full thruster power applied to lift jet engine from bottom. Able to slide engine along ocean bottom but unable to lift. Severe twisting occurs but claw swivel appears OK. Variable ballast is increased and claw attachment (with engine) released from vehicle for later retrieval.

1415 Vehicle brought on board YD197 and post dive inspection made. Video signal interference, and pan and tilt problems will be addressed during next week's operations. All other systems operating satisfactorily.

1500 Secured operations.
Time in water: 4 hours, 3 minutes.

1700 Task team departs for San Diego.

Monday, 23 Jul

0700 Task team departs for SCI from Jimsair.

0845 Task team arrives at YD197. Maintenance/repairs conducted in preparation for week's operations. The following is a recap of the day's work:

- WSP Pan and Tilt. Bang-bang units were connected to servos in effort to correct actuator control problems. Unit will be tested further during operations.
- WSP Pan and Tilt. Found ¼ cup of water in J-box. A pipe fitting, installed during refurbishment, was connected to an MS connector allowing water to pass through the O-ring. Repaired by installing proper fitting.
- Port Vertical Thruster. Small oil leak in shaft seal between prop and drive train. Not serious enough to hamper operations.
- Tool Valve Box. Broken control line to electronics bottle, apparently broken by personnel working on vehicle. Repaired.
- Rigging module. Prepared for next day's dive.

1645 Secured operations.

Tuesday, 24 Jul

0700 Task team arrives at YD197. Day spent continuing maintenance/repairs.

1700 Secured operations.

Wednesday, 25 Jul

0700 Task team arrives at YD197. Completed maintenance/repairs and preparation of rigging module for dive.

1346 Vehicle, with rigging module, launched and proceeding to test fixture area. Buoy line acquired with grabber and vehicle thrusted down to target. Buoy line released.

Manipulator acquires rigging module center hook from grabber. Lost visual contact with target and unable to relocate.

1508 Vehicle on surface. Repositioned over target guided by dive boat. Vehicle thrusted to bottom and begins search for target.

1524 Search aborted and vehicle on surface.

1616 Vehicle and rigging module on board YD197. Post dive inspection conducted and all systems found to be operational.

During checkout of drill/tap/bolt device, while onboard YD197, pressure increased and blew carbon face plate out in variable ballast pump. Unit needs relief valve installed to eliminate reoccurrence of this problem.

1700 Secured operations.
Time in water: 2 hours, 30 minutes.

Thursday, 26 Jul

0700 Task team arrives at YD197. Maintenance on vehicle conducted and rigging module prepared for dive.

1145 Vehicle, with rigging module, launched and proceeding to target area. Cable twist observed requiring 360 degree counterclockwise turn of vehicle to remove.

1213 Vehicle on bottom with target in sight. Manipulator acquires rigging module hook and vehicle positioned for hookup of rigging module to test fixture eye. After hookup and release of rigging module from vehicle, the slackout line was acquired and line takeup completed.

1322 Vehicle positioned for hookup of four rigging module lines to test fixture shackles. Vehicle maneuvering difficulties experienced. Cause unknown. Number one hook acquired in manipulator, lost, reacquired, and vehicle positioned on bottom for hookup. Hookup completed and takeup line acquired with grabber. Takeup assisted by manipulator. Mouse fails to snap onto shackle, secured through use of manipulator.

1520 Vehicle repositioned on bottom. Buoy line becomes caught on toolbox, and the box extended to try and remove line. The cutter tool is acquired in the manipulator, the line secured and cut. Tool is replaced in toolbox and the toolbox retracted.

Time required for tool acquisition and line cutting is 2 minutes, 30 seconds.

1544 Hook acquired and hooked onto shackle number two of test fixture. Time for hookup is 2 minutes, 15 seconds.

During this sequence the vehicle hit the test fixture. Unable to determine damage at this time.

1553 Positioning vehicle to grab onto test fixture when cable winch failed. Vehicle on bottom for 45 minutes while repairs made to the cable winch control.

1732 Vehicle on board YD197. Post dive inspection conducted and the following observed:

- Starboard Thruster. Leading edge of shroud damaged from apparent impact with test fixture. Shroud was contacting thruster blades.
- Compensating Oil Loss. Partial loss of compensating oil in electronics bottles. Cause unknown.

- Starboard Grabber. Upper actuator fitting bent from impact with test fixture.
- Upper Pan and Tilt. Problems in return to null position. Probable cause is bang-bang valve hookup to servo valve. Pan and tilt also had loose actuator shaft screws.

1800 Secured operations.
Time in water: 5 hours, 47 minutes.

Friday, 27 Jul

0600 Task team arrives YD197. Maintenance/repairs and preparations for dive completed on all items noted during previous day's post dive inspection. In addition:

- The lower PIV camera was relocated on the PIV forward floats to provide better viewing of operations.
- Hook positioned on toolbox for attachment to rigging modul for lift of target.

0900 Divers required for manual hookup of two remaining rigging module shackles since target was knocked over by the vehicle during the previous day's operations.

1102 Vehicle launched and proceeding to target area. Vehicle dove to bottom, hook acquired from toolbox and connected to rigging module. Time required for acquiring and hookup is 1 minute, 55 seconds.

1148 Vehicle positioned over target and variable ballast decrease started for lift off.

1157 Lift-off of rigging module and test fixture from bottom. Time to reach surface is 2 minutes. Umbilical cable is wrapped on top of vehicle. Vehicle dove below surface and two 360 degree turns completed for unwrap of cable. Rigging module and test fixture released from vehicle for retrieval later.

1243 Vehicle on board YD197.

1415 Secured operations.
Time in water: 1 hour, 47 minutes.

1630 Task team departs for San Diego.

Monday, 30 Jul

0725 Task team departs for SCI from Jimsair. Flight was scheduled for 0700.

0945 Task team arrives at YD197.

1000 YD197 generator failure. PWC support for replacement not available. Task team begins maintenance/repairs.

1100 Temporary moor repositioned to previously held position, approximately 50 feet down island from wing target. YD197 remained tied up in both moors over the weekend and during this time the offshore winds moved the temporary moor from its position. Decision made to untie from temporary moor at the end of each day's operations.

1200 Dive team dove for target inspection, clearing kelp as required.

Maintenance/repairs conducted for the day follow:

- Stop leak added to PIV generator radiator appears to have stopped leak. YD197 generator still inoperable.
- Banding clamps breaking at points of contact with aluminum. Zinc oxide applied to all affected areas.
- Loops (3-4) removed from umbilical cable by paying out over side of YD197 and rewinding.
- Continued debugging of Lift Module by NOSC, Hawaii personnel. Microprocessor not functioning.
- Began installation of slinging device onto vehicle for week's testing. Decision made to use BMI pump vice variable ballast system for target lift when using slinging device.

1630 Secured operations. YD197 power still not operational.

Tuesday, 31 Jul

0700 Task team arrives at YD197. Maintenance/repairs continued.

1815 Crane barge arrives with replacement generator. Maintenance/repairs conducted for the day follow:

- Pan and Tilt failed to go to full up position. Actuator spacing washer out of position causing stop prior to full up position. Unit repaired.
- Troubleshooting of compass uncovered faulty power supply in PIV electronics bottle and broken wire to compass. Twist counter failure attributed to this faulty power supply. Unit repaired and will be tested during following day's operations.
- Two exchanges of the slinging device, to be used for lifting the F4 target, were conducted on board the YD197. Unit was binding when sling assembly was extracted from the holder and during connection of the quick-disconnect to the sling. During initial hookup of the hydraulics, excessive back pressure was applied to the tool causing the hydraulic relief valve to open. The binding problem was resolved by grinding the mounting edges to provide adequate clearance. To eliminate the excessive back pressure, the hydraulic lines were shortened to reduce pressure. A decision was made to use the Battelle drive pump for supplying the jetting water to the sling assembly since the variable ballast pump spare parts were limited.

1830 Secured operations.

Wednesday, 1 Aug

0700	Task team arrives at YD197.
1000	Photographers arrive at YD197 after flight from North Island. Maintenance/repairs completed.
1215	Vehicle launched with slinging device attached for insertion under F4 target. The jetting hose was connected prior to launch to expedite operations. Vehicle proceeded to target and dove to bottom. Problems experienced in location of target.
1300	Target located and vehicle positioned on bottom to wait for photographers to reach target. Toolbox was extended and the slinging device removed for insertion under F4. Sling is difficult to see and needs to be marked for ease of visual contact. Time to remove sling from holder is 35 seconds.
1326	Vehicle is now positioned approximately 4 feet from target for insertion of sling. Inserting of sling begins. Difficult to see sling moving under target. Need to tape sling for reference on how much sling is moving. First try at inserting sling fails because vehicle not close enough to target. Experiencing video interference when high power tool pump is running.
1455	Begin second attempt at inserting sling. On this attempt the sling came up under the wing on starboard side of F4. At this point it was observed that the jetting hose was not engaged indicating loss of jetting for some portion of the operation.
1530	Third attempt at insertion of sling started. Sling is inserted to limit and end is observed in good position on starboard side of F4. Hook is acquired using manipulator and vehicle flown around aft side of F4 for hookup to sling. Sling fell over on side and current along with vehicle pull on hook line pulled sling from aft side of target. Decision made to abort attempt and retry during the following day.
1745	Vehicle aboard YD197. Notes for the day's operations follow: • During the post dive inspection it was noted that the starboard grabber wrist actuator was bent and large rocks thrown through the vertical thrusters caused extensive denting of the shrouds. Repairs will be made prior to the next day's dive. • Due to problems in observing amount of sling insertion, the sling will be marked with yellow tape for greater visibility. • The test plan will be revised for the following days's test to eliminate pulling of the sling from under the F4 when going around the aft end of target for connection of the sling hook. New procedure will be to fly vehicle to position above the F4 and drop the hook over for later retrieval and subsequent hookup.

- Umbilical cable caught on lead rack of PIV during return to surface. This problem will be eliminated during future dives by laying umbilical over starboard floats of PIV during launch vice over aft end of PIV.

1900 Secured operations.
Time in water: 5 hours, 15 minutes.

Thursday, 2 Aug

0700 Task team arrives at YD197. Maintenance/repairs on vehicle conducted and sling assembly prepared for day's operations.

1135 Dive team required to assist CURV project as no other divers available. Test on hold until task completed.

1330 Vehicle launched and proceeds to target.

1404 Vehicle approaching bottom and target in sight.

1407 Vehicle thrusted to bottom for positioning prior to sling insertion. Video interference experienced and starboard thruster appears to be hung up. Meters show current on starboard thruster is pegged at + 500 amps. Dive aborted and vehicle thrusted to surface.

1413 Blue smoke observed as vehicle surfaces and all power to vehicle shut down. Dive boat attaches tag line to vehicle and recovery procedures initiated.

1455 Vehicle on board YD197.

A post dive inspection was conducted and the following found:

- The starboard thruster lower shroud was jammed up into the thruster prop when the vehicle landed on rocks.
- The four vertical starboard thruster fuses were blown.
- The primary umbilical cable had a 1/4-inch hole in the potting just above the connector. Probable cause was power surge when vehicle hit bottom combined with deterioration of the cable insulation.

1730 Secured operations.
Time in water: 1 hour, 8 minutes.

Friday, 3 Aug

0600 Task team arrives at YD197. Perform maintenance/repairs.

Decision made to replace umbilical cable with spare. Crane Barge not available for transfer.

1430 Secured operations.

1600 Task team departs for San Diego.

Monday, 6 Aug

0700 Task team consisting of Wernli, Flood, and Osborn leaves Jimsair for SCI.

0815	Task team arrives at YD197. Crane Barge still not available for transfer of umbilical cable.
	Maintenance/repairs on vehicle performed.
1930	Secured operations.

Tuesday, 7 Aug

0700	Task team arrives at YD197.
1600	LCM arrives with umbilical cable for transfer to YD197. Cable transfer completed and dunk test of vehicle conducted to checkout cable. Sy em appears operational.
	NOSC, Hawaii personnel continue debugging of lift module. The magnetic reed switch is sticking in the closed position. Problem resolved by replacing unit with manually operated main power ON/OFF switch.
1930	Secured operations.

Wednesday, 8 Aug

0700	Task team arrives at YD197.
1000	Vehicle launched and proceeding to target for insertion of slinging assembly under F4. Vehicle positioned for bottom landing. Increased Variable Ballast (VB) to eliminate full vertical thruster down requirement to hold on bottom and approximately 5 seconds later (after VB activated) the WSP lost power. Approximately 45 seconds later the vehicle crashed to bottom due to full down power on the PIV thrusters. The 440 circuit breaker popped at this time. Vehicle was recovered using cable winch and dive boat.
1105	Vehicle on board YD197.
	Post dive inspection conducted and found the following:
	• Connector pins on both 440 cables to PIV electronics bottle blown out. Possible cause was connectors carrying heavy load and high contact resistance causing connector pins to overheat and blow out when variable ballast was activated. When blow out occurred, water entered the electronics bottle. When the water reached the depth sensor the unit reacted to the auto depth setting of 60 feet and caused vehicle to thrust full down to bottom and crash. The electronics bottle will be disassembled to assess damage and repairs required.
1330	Lift module off loaded from YD197 with crane and placed in water. Module is slightly buoyant. Divers add a 70 pound lead weight to bottom of module as ballast. A 1-inch hose was connected to the feed nipple and an on-board barge pump used to fill lift bag with water. Time required to fill bag to approximately 80 percent full was 1-1/2 hours. Feed hose was disconnected and the air switch turned on to force water out through discharge valve.

Divers find water connection to bottom of lift bag broken loose but will not affect air inflation. Inflation completed, the lift module recovered and placed on board YD197 with crane.

During inspection of the lift module it was found that the air inlet line plastic fitting was broken during recovery of the unit. In addition, foaming was observed, which appears to be electrolysis, in area of solenoid valve number two.

During the afternoon the PIV electronics bottle was disassembled and damages assessed. The following repairs will be required:

- Rebuild 3 AC contactors
- Build new 28V power supply
- Substitute ± 15V power supply
- Replace ± 10V regulator board
- Replace contact mike/diver control amplifier board.

1730 Secured operations.
Time in water: 1 hour, 15 minutes.

Thursday, 9 Aug

0700 Task team arrives at YD197.

Performed maintenance/repairs

- Commenced rebuild of electronics bottle. To conserve power the beacon and altimeter electronics have been omitted. The 440V power from the electronics bottle to transformer housing will be hardwired, which may help eliminate video interference experienced when high flow pump is running.
- Lift module repairs consisted of replacing broken plastic inlet line with metal nipple. Disassembled servo valve number 2 to inspect for short as possible cause of electrolysis. Discovered minor corrosion and replaced valve as precaution.

1100 Decision made to proceed with lift module testing using dive boat for transiting of module to targets, as waiting for rebuild of electronics bottle will waste valuable operating time.

The lift module is launched using the YD197 crane for retrieval of the jet engine and claw. Lift bag is fillled using barge pump while held alongside the YD197. Bag is now negatively buoyant and lift module is suspended approximately 10 feet below the surface.

1330 Dive boat tows lift module to target area and divers descend to target with lift module. Lift module line is fairleaded through to lift point on jet engine claw and air injected into the lift bag until slightly buoyant, at which time switch was turned off. Lift module then rose to position above target. Failure to adequately secure line allowed lift module to rise to 10 feet from surface.

Second dive team secured additional lead weights to module and pulled lift module to target. Lift wire from lift module was attached to jet engine claw.

Anchor line for weights was cut and module rose to position over target.

Air started for completion of lift bag fill. To speed up operations the main bypass valve was used for a short time (until relief valve opened) with the switch on. The V-2 bypass valve was used to put in just enough air to keep the relief valve operating periodically. Divers' air supply was low so switch was turned off and divers surfaced.

Decision made to secure operations for day. Dusk was approaching and without a complete dive team available it may have required aborting the lift in the middle of the operation. Therefore, a third dive team secured the lift module frame to the flat plate target and it was decided to continue the operation the following day.

Friday, 10 Aug

0600 Task team arrives at YD197.

0830 Dive team to lift module for inspection. The manual discharge valve had been left open. The buoyancy of the remaining air in the bag caused the water to be slowly forced out, thus deflating the previous "rigid" lift bag. The valve was closed, and the pumping system tested and found to be operational. A "break out or reference buoy" was left coiled on one handle of the lift module. This buoy will be anchored approximately 5 feet from the lift module floating at a level parallel to the lift module frame top. This reference will be used to allow dive team observers to determine more accurately when "break out"occurs.

0900 Decision made to secure testing for day due to the following factors:

— WSP/PIV still not operational.

— Crane operator scheduled for flight off SCI at 1100 and no other operators available.

— No military divers available and only one set of task team divers with dive time remaining. Pumping operations will require two to three sets of divers for lift-off and retrieval.

— Photography divers out of dive time for recording operations.

— The lift module was positioned on the bottom, a safety line attached from the module to the flat plate, and a pinger affixed to the lift module.

Day will be spent performing maintenance/repairs on vehicle and rebuild of electronics bottle.

1400	Secured operations.
1730	Task team departs for San Diego.

Monday, 13 Aug

0700	Task team departs for SCI from Jimsair.
0820	Task team arrives at YD197.
1100	YD197 riggers late arrival delayed mooring to the temporary 2-point moor. Day's operations were as follows: Dive team removed the anchor line which secured the lift module to the flat plate for the weekend. The lift bag was then partially filled with water from a portable pump in the dive boat. The fill hose was connected to the submerged module by the divers. Once connected and filled, the final lift phase took approximately 11 minutes. Lift module with claw and jet engine was towed to YD197 by dive boat and recovery completed. Repairs continued on the electronics bottle.
1900	Secured operations.

Tuesday, 14 Aug

0700	Task team arrives at YD197. Maintenance/repairs performed on vehicle.
1100	Task team on shore as requested, by Range Safety Officer, for pending Tomahawk shot.
1400	Task team returns to YD197. Maintenance/repairs on vehicle continued. Electronics bottle repairs completed. Dive team reinstalls number one sling assembly on aft end of F4 to expedite demonstration of lift for tomorrow's visitors.
1630	Secured operations.

Wednesday, 15 Aug

0700	Task team arrives at YD197.
0800	Program sponsor and team arrive for viewing of test operations. Scheduled operation for day is rigging of F4 with slinging device. Sling assembly will be inserted on forward end of F4, and connected to aft sling assembly installed by divers yesterday.
0952	Vehicle launched with sling assembly and proceeds to target area.
1025	Vehicle positioned on bottom for sling insertion. Tool box is extended and sling assembly lifted off with grabber. Sling assembly secured in manipulator, insertion procedure started and jetting pump turned on. Difficulties experienced in last few feet of insertion due to rocks on bottom. Grabber was used to move sling assembly to side for bypassing of obstacles and the sling assembly raised for better insertion angle. Sling assembly caught in hole in F4, backed out and insertion completed at 1139.

	Quick disconnect hose released using manipulator and placed in grabber. Manipulator used to obtain sling hook and chocking line stretched out. Vehicle flown to position above F4 and hook dropped over to starboard side of F4 for retrieval and hookup.
1225	Vehicle flown around aft end of F4 for retrieval of hook and threading through sling. Hook obtained with manipulator and threading completed. Time to acquire and thread through sling is 6 minutes, 30 seconds.
	To expedite operations, the dive team attached a garland ring, with buoy attached, to the F4 for sling hook attachment. Vehicle was then flown up over F4 for attachment of sling assembly hook to garland ring. Hook line became taunt and hook was pulled from manipulator. Starboard grabber stopped operating and decision was made to finish operations during the next day's dive.
1435	Vehicle aboard YD197. Post dive meeting held with sponsor for discussion of program objectives and the day's operations problems.
	Post dive inspection conducted and the following observed:
	• Starboard grabber pressure and return quick-disconnect lines released causing power loss. During operations the grabber hit the F4 several times causing the quick-disconnects to release. These floating units have 1/4-inch of travel which was not enough to compensate for the impact.
	All other systems are operational.
1800	Secured operations. Time in water: 4 hours, 13 minutes.

Thursday, 16 Aug

0700	Task team arrives at YD197.
	Maintenance performed and lift module prepared for day's operations.
	Dive team to F4 for repositioning of garland ring to ensure sling assembly hook will reach for connection.
1100	Vehicle launched.
1105	24V power supply fuse blows causing generator shut down. Cause unknown. Fuse replaced and vehicle proceeds to target area.
1139	Target in sight but experiencing unequal power draw on starboard and port thrusters. Vehicle surfaced for check. When feathering, power draw is not equal. Problem probably in electronic control cards. Decision made to continue operations.
1153	Vehicle on bottom. Sling assembly hook obtained in manipulator and vehicle flown above F4 for hookup with garland ring. Connection made on first try. Vehicle brought to surface to wait for completion of lift module preparations.

1410	Lift module still not operational at this time. Decision made to conduct test sequence with toggle bolt assembly on flat plate. Diver used to insert toggle bolt assembly in grabber to eliminate recovery of vehicle.
1420	Vehicle proceeding to target but heavy down island currents and wind stop vehicle headway. Unable to proceed even under full thruster power.
1510	Decision made to abort operations and recovery started. Unable to maintain control of vehicle against wind and current. Vehicle is swept back to YD197 and collision imminent. Vehicle dove to avoid collision. Vehicle under YD197 for approximately two minutes, during which time the line to the temporary moor was released allowing the YD197 to swing with the current to clear the WSP/PIV. Tag line attached by dive boat and recovery initiated.
1535	Vehicle aboard YD197.

Post dive inspection conducted and the following observed:

- Cross cut on umbilical cable outer skin of 2 inches probably caused while vehicle under YD197.
- Port vertical thruster shaft seal leaking. This has been a reoccurring problem during operations and has presented no operational problems to this point.

Notes for lift module repairs for the day follow:

- On/off switch in off position but solenoids continued clicking.
- Solenoid valve number 2 shorted out during the troubleshooting procedures.
- Bad contact on J2 pins.
- Terminal board required rewiring.
- Battery box connector broken.

All problems corrected and system operated properly for five consecutive tests. All systems deemed to be operational for next day's dive.

1630	Secured operations. Time in water: 4 hours, 35 minutes.

Friday, 17 Aug

0600	Task team arrives at YD197.
0645	Informed by Range Officer that no crane operator available for operations.
	Maintenance performed.
1430	Task team departs for San Diego.

Monday, 20 Aug

0700	Task team departs for SCI from Jimsair.
0840	Task team arrives at YD197. Maintenance of vehicle and preparation of lift module completed for day's operations. Test sequence will be lift of F4 with lift module and previously inserted sling assemblies.
1200	Lift module launched with YD197 crane and prepared for mating with vehicle.
1230	Vehicle launched and mating to lift module completed.
1240	Vehicle/lift module dove to F4 target. Lift module positioned on bottom. Manipulator used to acquire lift module toggle for connection to garland ring. Vehicle flown over F4 and toggle secured to garland ring.
1355	Commence remating of vehicle with lift module. Mating procedure time was 15 minutes. Hydraulic manifold acquired from lift module by manipulator. Time to acquire was 7 minutes. Water fill of lift bag started to raise lift module to overhead position. Hydraulic manifold returned to stowed position.
1448	Reacquired hydraulic manifold and began pumping air into lift bag. Tool not inserted properly in manipulator causing improper quick-disconnect mating. Regripped tool. Quick-disconnect still not mated properly.
1535	Dive team repositions hydraulic tool in manipulator but unable to connect. The lift module was near the surface at this time. Lift module was repositioned on bottom next to target by divers.
1715	Lift module anchor line attached and test operations secured for day. Recovery procedures for vehicle initiated.
1844	Vehicle aboard YD197. Post dive inspection indicated all systems operational.
1930	Secured operations. Time in water: 6 hours, 14 minutes.

Tuesday, 21 Aug

0700	Task team arrives at YD197.
0800	Dive team to target to remove lift module anchor, untangle toggle line, close top valve on lift bag and reposition lift bag for filling. Replaced quick-disconnects on hydraulic manifold to eliminate mating problems experienced during previous day's operations..
0915	Vehicle launched and proceeding to target.
0934	Vehicle positioned on bottom next to F4. Lift module toggle acquired with manipulator. Vehicle backed away from the target to lock main snap hook lift line to the lift point. The vehicle was mated in midwater with the lift module and the hydraulic manifold acquired for pumping water into the lift bag.

1225	After filling the lift bag with water, the hydraulic manifold pump switch is reversed for pumping of air into lift bag for F4 lift. Prior to lift-off the PIV is set on bottom away from the target.
1415	Tail section of F4 begins to lift.
1424	Lift-off of F4 complete and lift bag on surface. Time required for pumping of air: 1 hour, 18 minutes. After floating on the surface for approximately 10 minutes, the manual air relief valve was opened, and the lift module and F4 were repositioned on the bottom.
1600	Vehicle aboard YD197. Post dive inspection indicated all systems operational. Maintenance performed on vehicle.
1930	Secured operations. Time in water: 6 hours, 45 minutes.

Wednesday, 22 Aug

0700	Task team at YD197.
	Prepare vehicle for operations. Purpose of day's dive is to obtain additional photographic coverage of the F4 lift.
0845	Vehicle launched and proceeding to target.
0921	Vehicle in position on bottom. Divers inspect lift module and partially fill lift bag to raise just off the bottom. Divers position hydraulic manifold in manipulator. Manifold tested and bad locking "spider" on quick-disconnect discovered. New disconnect sent to dive team for installation. Hydraulic leak still exists after replacement.
1025	Divers out of water due to diver accident, on another project, at Wilson Cove requiring use of the recompression chamber. Operations secured with vehicle still positioned on bottom.
1245	Operations resumed. Decision made to proceed to testing of toggle bolt assembly on flat plate. Vehicle brought to surface, divers clear kelp from vehicle and reposition umbilical cable which is hung up on top of vehicle.
1316	Vehicle positioned on bottom next to flat plate. The jet engine, which had been removed from the crane barge after recovery, is positioned just in front of and on starboard side of flat plate. Vehicle is repositioned due to interference of jet engine and large rocks hampering work area.
1349	Vehicle repositioned and tool box extended. Toggle bolt removed from holder using manipulator. Time to acquire is 1 minute, 20 seconds.
1354	Begin try for insertion and locking of toggle bolt into pre-drilled hole in flat plate. Three trys required for successful insert/locking procedure. To lock toggle bolt a 180° turn must be taken on the pad eye. Times to insert were 6 minutes, 20 seconds; 1 minute, 55 seconds; and 1 minute, 5 seconds. Toggle locked in at 1415. Reposition vehicle for insertion of second toggle bolt.

1520 Receive all clear to dive from Diving Locker and divers dive for photographic assist with operations.

1521 Manipulator attaches to second toggle bolt and removes it from holder. Time to acquire is 2 minutes, 15 seconds. Insert toggle bolt in hole of flat plate. Two tries required. Times to insert were 1 minute, 5 seconds, and 1 minute, 35 seconds. Experienced minor problems with locking the toggle bolt into position. The problem can be solved through minor design changes. Toolbox retracted and operations suspended.

1605 Vehicle aboard YD197.

Post dive inspection conducted and the following observed:

- A line, origin unknown, caught on port thruster shaft tearing the shroud retaining ring and bottom cowling loose. The shroud was dented and the bottom extended in towards the thruster prop.
- Port thruster prop shaft seal leak increasing in volume.
- Cowling on forward athwart thruster was bent in toward prop due to kelp being sucked in.

1830 Secured operations.
Time in water: 7 hours, 5 minutes.

Thursday, 23 Aug

0700 Task team at YD197. Perform maintenance/repairs.

1240 Vehicle not operational. Dive team proceeds to test area to obtain additional photographic coverage of the F4 lift. A portable pump is placed on the dive boat and is used to fill the lift bag one-half full of water. The switch for air fill is activated and the bag fills to near break out point. At this point air is escaping through the relief valve due to a water dump valve failure. Test was aborted.

1815 Lift module recovered and aboard YD197.

Maintenance/repairs consisted of the following:

- Repairs on the port thruster required the removal of the prop shaft seal. The thruster shaft was scored beyond a field repairable status. A new seal was installed and the hydraulic compensation line to lower portion of shaft was capped off. This is possible because operations are in shallow water. The shroud dents were repaired and the shroud secured with banding clamps. The thruster upper cowling was used to replace the damaged lower cowling to prevent impact with rocks.
- The net deployment assembly was prepared for the next day's operations.

1900 Secured operations.

Friday, 24 Aug

0700	Task team at YD197. Test operations for day will be the deployment of the net assembly.
0755	Vehicle launched and proceeding to target. The weight of net assembly requires holding cylinder release switch in reverse (on position) to prevent premature release of net.
0831	Net released from vehicle and vehicle positioned behind net on bottom. Had to reposition vehicle as it had landed on F4 target.
0848	Pumping tool acquired in manipulator and onto manifold for filling of net. The drill motor tool appeared to be binding intermittently when activated, possibly caused by corrosion.
0859	Net is semi-deployed. Hung up on PIV. Diver had to free net from vehicle.
0910	Drill tool back in toolbox. Disconnect fill hose from toolbox. Turn valves (2) to close. Tool box retracted.
0947	Vehicle aboard YD197.
1045	Launch vehicle for E1B destruction sequence using cutting/drilling tools.
1108	Upper WSP TV failure. Maneuvering around E1B. Too much kelp and visibility bad with other TV. Unable to perform tool sequence.
1210	Vehicle aboard YD197. Post dive inspection conducted and the following observed: • Broken compensating oil line on port grabber valve box. • One turn in umbilical cable.
1400	Vehicle/equipment secured for transit of YD197 to San Diego. Secured operations. Time in water: 4 hours, 15 minutes.
1615	Task team departs for San Diego.

Monday, 27 Aug

—	YD197 taken under tow by Pacific Towing for transit to NOSC, San Diego.

APPENDIX B
WSP/PIV PROBLEM AREAS

Table 1. WSP/PIV Problem Areas

Component	Problem	Cause/Result	Fix
PIV Control Console	Indicator lights fail.	Defective 9V Power Supply. Thermal problem inside unit.	Replaced with alternate 9V P.S.
PIV Control Console	Auto Altitude functioned as if controls reversed.	Misread dial gauge.	Update Operations Manual.
PIV Control Console	Compass failed to function.	Faulty Power Supply in instrument can electronics. Broken wire in compass housing.	Replaced power supply and reconnected wire.
PIV Instrument Can Electronics	Housing flooded with water, due to failure of 2 bulkhead high pressure under water connectors.	Cause: Still under investigation but some areas of consideration are: high contact resistance of connector, failure of water tight integrity of connector.	Rebuild 3 AC contactors. Build new 28V power supply. Substitute ± 15 power supply. Replace ± 10V regulator board. Replace contact mike/diver control amplifier board.
PIV Thrusters	Prop lower shaft seal leaking.	Deteriorated seal caused scoring of prop shaft to a non-field repairable condition.	Installed new seal and capped off hydraulic compensation line to lower portion of shaft.
PIV Thrusters	Shroud/cowling damaged.	Line caught in prop of port thruster tearing shroud retaining ring and cowling loose.	Replaced with upper shroud/cowling.
PIV Thrusters	Uneven power draw between Port and Starboard when feathering.	Problem probably lies in control	Not hampering operations so no fix performed at this time.

Table 1. WSP/PIV Problem Areas (Cont.)

Component	Problem	Cause/Result	Fix
PIV Thrusters	Power loss to thrusters due to excessive travel of variac output voltage wiper arm. Limit switches activated.	Reduction of 15V reference voltage for feedback to auto transformers. Transformers locked open activating limit switch, removing power from the thrusters.	Removed excessive load from 15V reference power supply.
PIV Thrusters	Lost power.	Vehicle landed on rocks jamming lower thruster shroud in prop. Blew 4 starboard vertical thruster fuses and blew 1/4" hole in primary cable at connector.	Replaced umbilical cable. Straightened shroud.
Pan and Tilt	Upper Pan & Tilt pans to left stop and will not return.	Leak in vane actuator seal.	Installed spare Pan and Tilt.
Pan and Tilt	Actuator problems	– – –	Connected bang-bang units to servos.
Pan and Tilt	Signal interference between PIV video and WSP pan and tilt.	Grounding signal interference in cable.	Shut down PIV video power when WSP pan and tilt in use.
Pan and Tilt	1/4 cup of water in J-box.	Pipe fitting, installed during refurbishment, connected to MS connector allowing water to by-pass o-ring.	Installed proper fitting.
Pan and Tilt	Would not return to null position.	Shorted wire.	Traced and repaired.

Table 1. WSP/PIV Problem Areas (Cont.)

Component	Problem	Cause/Result	Fix
Pan and Tilt	Failed to go to full up position.	Actuator spacing washer out of position.	Reinstalled spacing washer.
Grabber	No power on starboard grabber.	Pressure and return line Quick-Disconnects released when grabber hit test fixture.	Reconnected Quick-Disconnects.
Syntactic Foam Banding Clamps	Clamps breaking at points of contact with aluminum.	Galvanic Corrosion	Zinc oxide applied. Should install plastic spacers in future.
Tool Valve Box	Broken control line to electronics bottle.	Personnel working on vehicle.	Repaired.
Cable Winch	Failed to function.	Intermittent open in cable.	Unit began operation on its own. Cable should be replaced.
Cable Winch	Umbilical cable lags when rewinding.	Improper gearing of cable winch level wind.	Design should be reevaluated.
Variable Ballast Pump	Cracked carbon face plate.	Overpressurized line during DTB testing.	No replacement available. Requires relief valve in line to prevent recurrence.

APPENDIX C
CLAW ASSEMBLY

Background

The claw assembly provides a grasping similar to that used for torpedo recovery and was used during SCI testing to provide an attachment point for the lifting of a jet engine. This test provided data on attachment/lift feasibility for aircraft components under 2,000 pounds. The claw assembly works on an ice-tong effect in that when the trip lever is activated, the claw closes encompassing the target in its grasp.

Slight modifications were required for use of the claw in WSP/PIV testing. The original design of the claw assembly included the installation of stops to ensure that the tongs did not travel beyond the terminal point of closure. This prevented a tight grasp of the jet engine during SCI operations. A trip cable was installed to allow the WSP manipulator to trip the claw into the closed position. A mounting bracket was installed on the WSP toolbox to allow easy acquisition by the WSP manipulator. Modification to the PIV included the installation of a crossbar with a hydraulically actuated locking shaft to the lower frame of the PIV to provide a mating point between the claw and vehicle.

Operational Scenario

The object of this test series was to capture a jet engine in the claw assembly, to rig for a single point lift, and to recover using vehicle thrusters and variable ballast for the lift force. The following paragraphs give in detail the operational scenario for the claw assembly. Any deviations from the normal scenario are included.

1. Sampson line is attached to the top of the claw and runs through claw attachment on PIV, over PIV roller and through two pulleys and out aft end of PIV. The line is then secured to the capstan winch (Figure C-1).
2. WSP/PIV is raised with the YD197 crane, positioned over the claw and the claw pulled into PIV claw attachment point using the winch. The locking shaft is then hydraulically actuated to secur the claw in position and the sampson line removed. Claw is in open position. Launch is completed with the WSP/PIV and claw mated (Figure C-2).
3. Vehicle is then positioned directly over the target so that the claw encompasses it. With the vehicle hovering over the target, the manipulator acquires the trip line (positioned on the toolbox) and pulls the line to trip the claw to the closed position.
4. The variable ballast is decreased and thruster power increased for lift-off. Due to the lower than anticipated thrust from the PIV, we were unable to achieve lift-off of the target but were able to move target along the bottom. Subsequent dive was made and successful lift made using Lift Module.

Test Results and Conclusions

A jet engine was successfully captured and lifted from the ocean bottom during SCI testing. Upon initial capture an attempt was made to raise the engine using the PIV thrusters assisted by a decrease in variable ballast. Although calculations had determined the in-water weight of the engine to be 1,916 pounds and data provided on the PIV indicated thrus er capabilities for a 2,000 pound lift, we were unable to achieve lift-off. Subsequently, the LM was used to perform the lift-off of the engine and claw. The following observations were made while at SCI:

a. Fore and aft movement of the claw during transit to the recovery area was minimal though severe twisting did occur to the mating connection.

b. Camera placement requires improvement to allow visual display of claw position in relation to the target when attempting capture.

c. Experienced some difficulties in activation of trip mechanism. Redesign is required to allow operator visual confirmation that claw has been tripped to closed position.

d. For this task, a master slave manipulator would possibly be beneficial since most of the operation is mid-water which requires quick action. Suggest a time-motion study for comparison purposes.

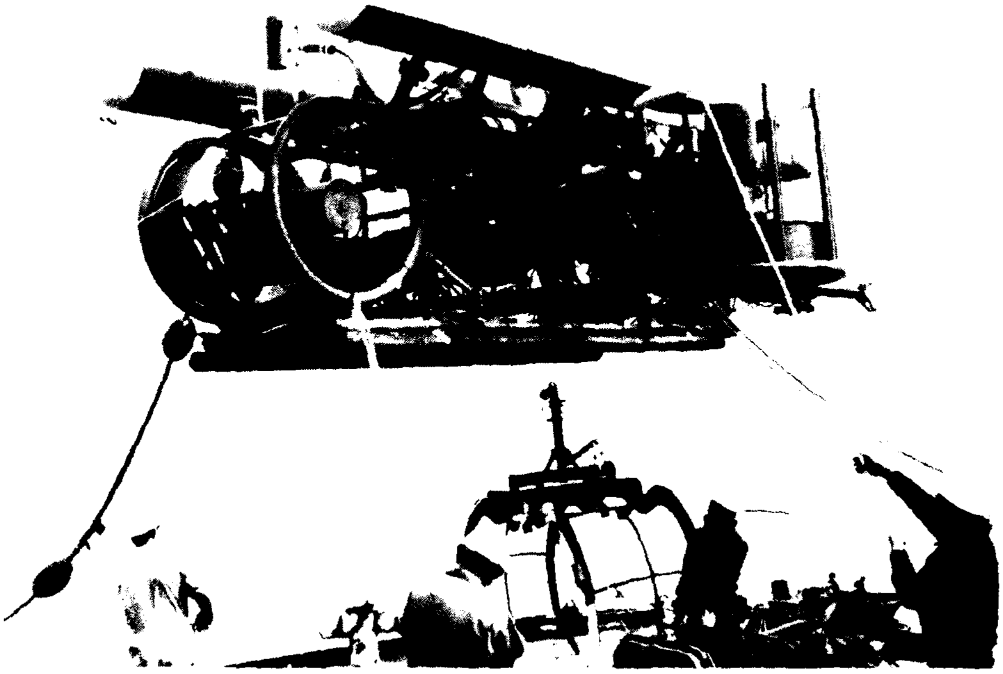

Figure C 1. Mating of claw assembly with PIV.
(LRO 3530-8-79B)

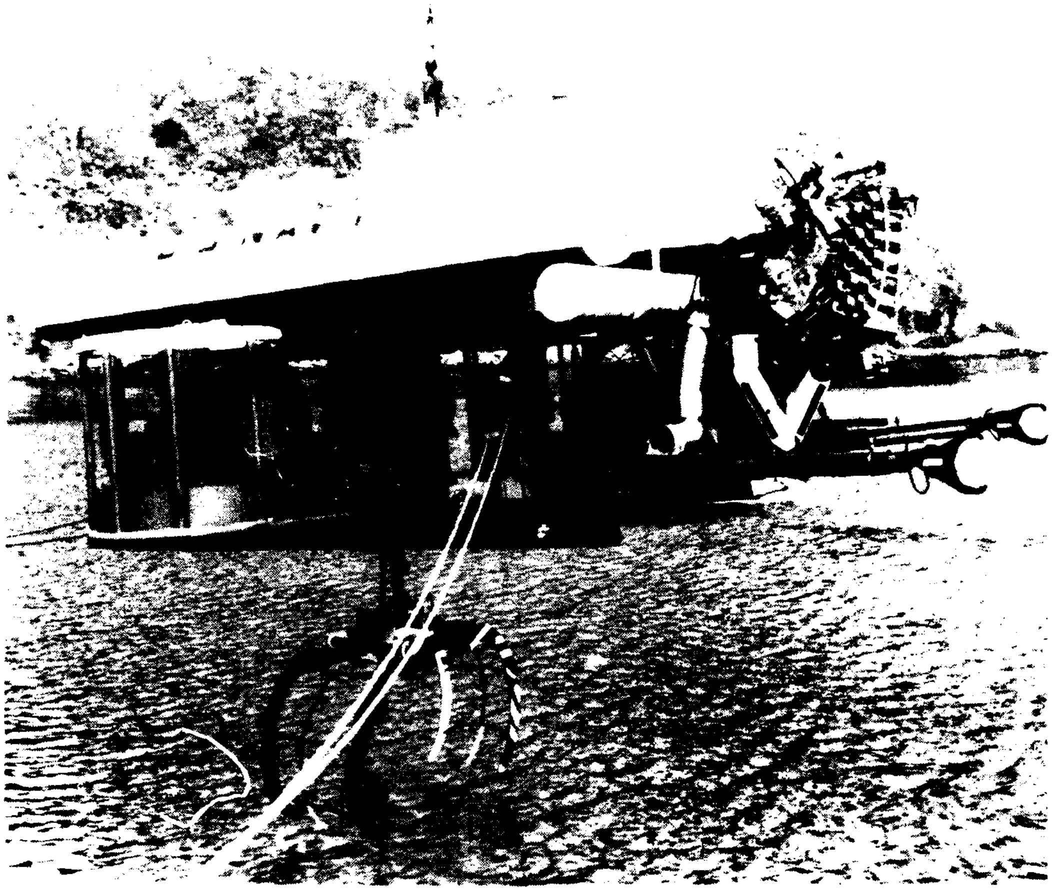

Figure C-2. WSP/PIV launch with claw assembly attached.
(LRO 3536-8-79B)

APPENDIX D
LIFT MODULE

Background

The Lift Module (LM) (Figure D-1) was developed to demonstrate the feasibility of utilizing a fixed displacement lift bag with a self-contained gas source as a means of transporting an object from the ocean bottom to the surface. This method eliminates the unreasonably high power requirements which would be required to lift a 10,000-pound object using vehicle thruster power.

The LM is a submersible system with the lifting force provided by a 150 cubic foot, air filled, fixed displacement KEVLAR lift bag. Constant bag volume is accomplished by a relief valve (Figure D-2) which maintains internal bag pressure at 5 to 10 pounds over ambient pressure. Buoyancy can be varied by forcing water into or out of the lift bag.

System operation is controlled primarily through a preprogrammed microprocessor. The microprocessor receives inputs from the hydrostatic depth transducer, compressed air flask, and the bag pressure control switch. It can also receive commands from the WSP via hydraulic pressure pulses or, in an emergency, via a magnetic switch. The microprocessor utilizes these inputs to control both air and water flow to and from the lift bag.

Initially, the WSP operator energizes the hydraulic motor/seawater pump after acquiring the interface manifold (Figure D-3) and cycles hydraulic fluid through the manifold in the forward direction. This pumps water into the lift bag. Reversing the pump reverses the flow and builds up pressure at the pressure switch, activating the microprocessor. A pump energizing sequence of STOP, REVERSE, STOP, REVERSE, STOP done in less than 5 seconds, will generate two pressure pulses and signal the microprocessor to open the proper valves. The high pressure supply valve opens and allows air to flow into the bag while low pressure supply valve opens for water discharge. The water discharge relief valve creates a 5-psi back pressure which maintains constant lift bag volume during changes in buoyancy. When a single pressure pulse is generated the microprocessor closes the valving system. This may be done at any time in the manual control sequence to shut down the air supply to the bag.

The LM is designed to operate in the "manual mode" in the depth range from ocean bottom to 75 feet above the bottom. Once the LM is above this level, the microprocessor shifts to the "automatic mode" to control the ascent to the surface. The microprocessor utilizes inputs from the depth sensor and the bag pressure control switch to maintain a constant ascent velocity of 1/2-foot per second during automatic operations.

Excessive accelerations/decelerations sensed through the depth sensor will cause the microprocessor to close valves or turn off the pump as required. The bag pressure switch maintains a constant internal bag pressure. Should the internal bag pressure rise above 8 PSI over ambient while air is being pumped into the bag, the microprocessor will close the high pressure supply valve. Water will then be forced out through the water discharge valve since it will remain open. Once the internal pressure has fallen below 6.5 PSI over ambient, the high pressure supply valve will open allowing air to be introduced until the proper buoyancy/ascent rate is achieved.

If the WSP/PIV LM interface is maintained after the microprocessor has shifted to "automatic" control, manual control may be regained. This is accomplished by a one-pressure pulse signal to the microprocessor. The microprocessor is now in manual control and will no longer shift into "automatic"; ascent and descent control are a function of the WSP/PIV operator.

Should a failure occur in either the LM or WSP/PIV hydraulic system, the microprocessor can be operated by a magnetic switch. The switch is located on the control panel on the front of the LM. Switch activation is accomplished by touching the attached magnet to the black switch surface. When the magnet is in place, the switch is closed; when the magnet is removed, the switch is open. This switch is in parallel with the hydraulic control switch and is used in the same operating sequence. Two closures of the magnetic switch separated by less than 5 seconds will activate the microprocessor and air will be pumped into the lift bag. One switch closure will stop the flow of air to the lift bag.

It should be noted that only positive buoyancy changes can be made with the magnetic switch. This feature is to facilitate emergency recovery of the LM. The microprocessor will shift to "automatic" after it has risen 75 feet off of the bottom. Only after this has occurred can the microprocessor pump water into the lift bag to slow the ascent rate.

Should a failure occur in the microprocessor or related electronics, manual bypass valves have been provided to facilitate LM recovery. To initiate LM ascent by this method, the manual fill ball valve should be opened. Air can be bled into the lift bag by opening the bypass valve located on the control panel. After the LM has been slightly positive, both valves must be closed. The LM will then rise to the surface; expanding air will vent from the lift bag. Ascent control may not be maintained in this mode. Care must be taken to ascend slowly.

Upon initial object bottom break-out, the microprocessor is capable of controlling module ascent in a preprogrammed manner and no external control is then required. Control over the ascent rate is required to ensure that the additional dynamic load of the recovered object stays within 10 percent of its static load. In addition, the ascent rate must be such that the venting capacity of the relief valve is not exceeded. When the Lift Module/Object approaches the surface, the lift bag will break the surface leaving the module and object suspended beneath the surface for salvage/recovery operations.

Operational Scenario

The prime object of the lift for the LM was the F4 aircraft. The test sequence is as follows:

1. Launch vehicle.
2. Launch LM with crane and attach tag lines. While positioning LM with tag line vehicle mates to LM with grabbers acquiring attachment points on the port and starboard sides of the LM.
3. Position LM on bottom and acquire toggle, attached to steel cable running to bottom of LM, and connect to lift point of object (F4 jet).
4. Position vehicle, mate with hydraulic manifold of LM, activate for air fill until ≅ 50 pounds buoyant, return manifold and release module. The LM rises overhead of F4.

5. Reacquire toggle (on light 1/4-inch line) from other side of attachment point, and back vehicle off pulling LM down so snap hook on end of primary lift line attaches to attachment point on test object.
6. Dock in mid-water with LM. Partially fill lift bag with air (but not enough to lift) and then complete fill with water, creating a rigid pontoon.
7. Undock from LM taking hydraulic manifold (100-foot line attached) and position vehicle on bottom.
8. Continue filling with air until lift-off.
9. Either ascend vehicle with object or release hydraulic manifold to allow it to rise under LM microprocessor control.

Test Results and Recommendations

A successful lift of an F4 aircraft and a jet engine, both using the LM, was conducted during testing at SCI. Remote operation of the LM through the use of a tethered vehicle and in addition, diver control was demonstrated. A log of critical events and recommendations follows:

a. (25 July) Upon arrival and assembly of the LM, it was determined that the microprocessor was not functioning properly. Difficulties were encountered because specialized equipment, specific schematics and specifications required for effective microprocessor troubleshooting were not immediately available. Enough data was collected during the troubleshooting process to determine that the microprocessor could not be repaired readily with the resources allotted. Since a test sequence change forced all lifts to be made from less than 100 fsw, as opposed to the 600 fsw originally planned for the LM, the impact of removing the microprocessor from the LM system would be minimal. The short distance travelled during ascent (less than 60 fsw) negates the need for the fine control capability of the microprocessor. The LM circuitry was rewired to eliminate the microprocessor.
b. (8 August) During a wet test of the LM, difficulty arose in determining the water level within the lift bag. This problem will be addressed in future design modifications. Recovery of the LM after the wet test could not be accomplished until the lift bag was drained completely which required approximately 40 minutes. A quick dump system or some other method is required to reduce dewatering time. The length of the discharge hose was reduced while its diameter was increased to assist in reducing deballasting time.
c. (9 August) Towing of the LM to the work site with the lift bag fully deployed presented no problems.
d. (13 August) The LM was left in the water over the weekend giving it an elapsed in-water time of 96 hours. During this time a slow leak in the electronics pressure housing shorted out the entire electrical system. The LM was activated in the manual bypass mode by a diver for retrieval. Once "breakout" occurred, the manual air bypass valve was closed.

Repair of the electrical system was started. It was determined that one of the hull penetrators on the microprocessor pressure housing developed a slow leak. The result was that the microprocessor chassis was one-third submerged in salt water.

The microprocessor chassis was cleaned with fresh water and then solvent. It was then removed entirely from the LM to preclude further damage. Inspection and testing of the microprocessor revealed minimal damage due to salt water immersion.

During subsequent testing the LM began showing signs of erratic behavior. The source of the problem was again found in the pressure housing which contains the microprocessor. The pins on the hull penetrator which had leaked were severely corroded due to the combination of salt water residue, dissimilar metals, and current flow.

The hull penetrator was replaced and sealed with a Silastic compound. The two pins (24 VDC and ground) were rewired to provide maximum separation. No further difficulties arose in the electrical system during the remainder of the operations.

e. (10 August) When left in water overnight the manual water discharge valve was inadvertently left open causing all of the water in the lift bag to drain. The valve was closed and the bag refilled with water.

   Upon recovery, several modifications were made to the LM water discharge system. The manual water discharge valve was moved closer to the control panel to preclude it being inadvertently left open in the future.

f. (20 August) Difficulty was experienced in the hydraulic interface between the WSP and the LM. On the surface, the WSP manipulator mated easily with the lift module hydraulic manifold. However, when submerged, the mating process required diver assistance. The problem appears to have been caused when the quick-disconnects were overpressurized internally during improper mating. The result was that the male and female portions of the quick-disconnects would not mate properly without divers releaving the internal pressure. This problem should be easily corrected.

g. (21 August) A failure of the diaphragm in the water discharge valve was experienced after completion of the F4 lift. In addition, minor problems were encountered with sand contamination due to the PIV prop wash which identifies the need for a better water pump filtration system.

As anticipated, there was a severe lack of feedback from the LM to the WSP operator. The visual feedback was slow. It should be noted that during this operation, time was of the essence because divers were required to photograph all important events. Coordination of events with limited diver bottom time was difficult because of the lack of LM feedback.

Under normal circumstances where diver bottom time is not a factor, slow lift module operation and minimal feedback may be more acceptable. However, the following improvements should be considered for future LMs:

1. Real-time feedback indicating the system is operating properly (ie, air is entering the lift bag and water is actually leaving the lift bag) should be included.

2. During remote operation of the LM, the WSP operator does not have good visual contact with of the lift module. Therefore, a remote, visual display of system status located on the side of the hydraulic manifold would be appropriate. Better camera placement allowing overall viewing at the lift bag would also be desirable.
3. Feedback data to the WSP operator should include either a load cell readout or indication of water level within the lift bag (ie, sight glass arrangement).

Figure D-1. Lift Module.
(LRO 3416-8-79)

Figure D-2. Lift Module relief valve.
(LRO 3931-9-79B)

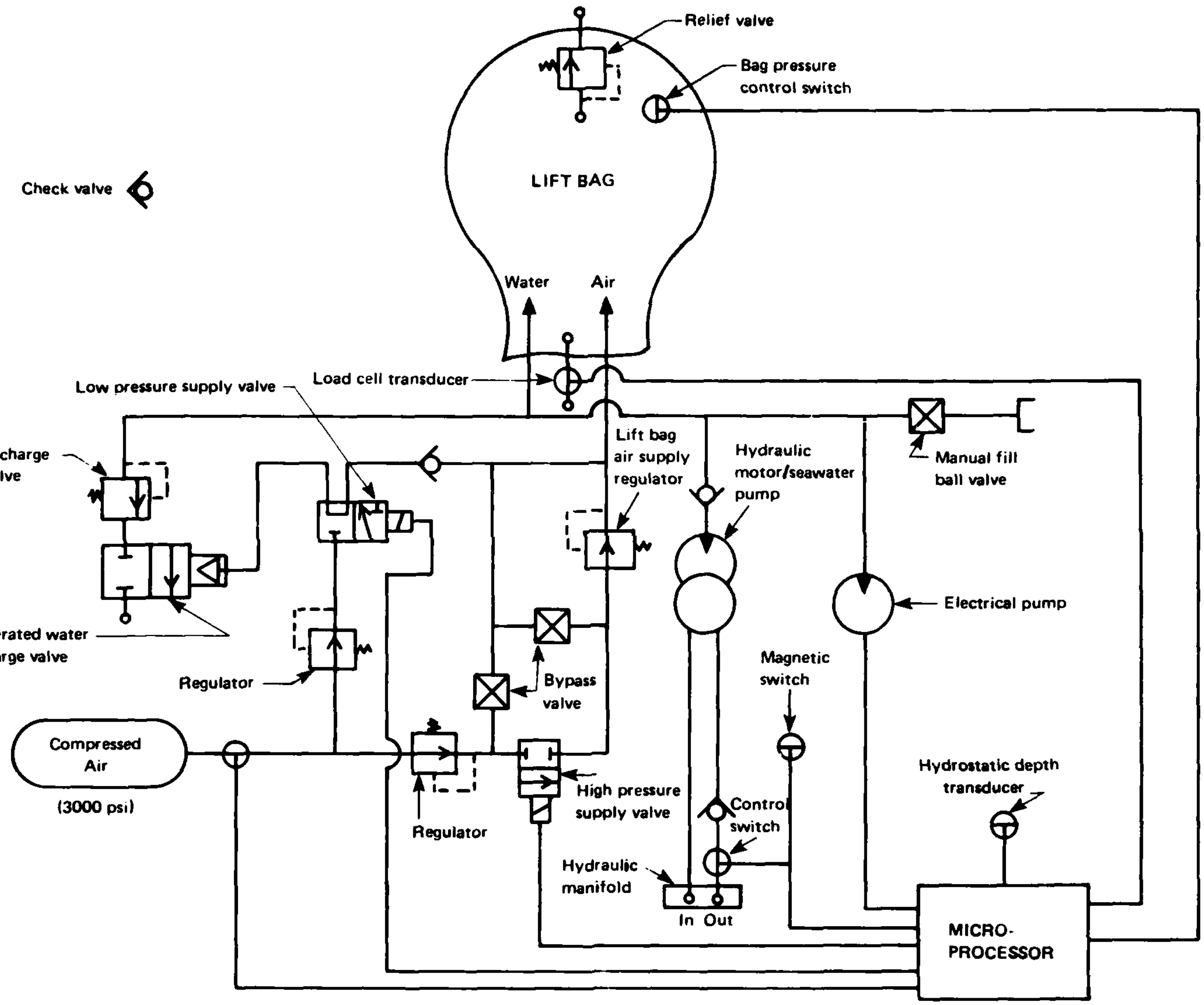

Figure D-3. Lift Module control system diagram.

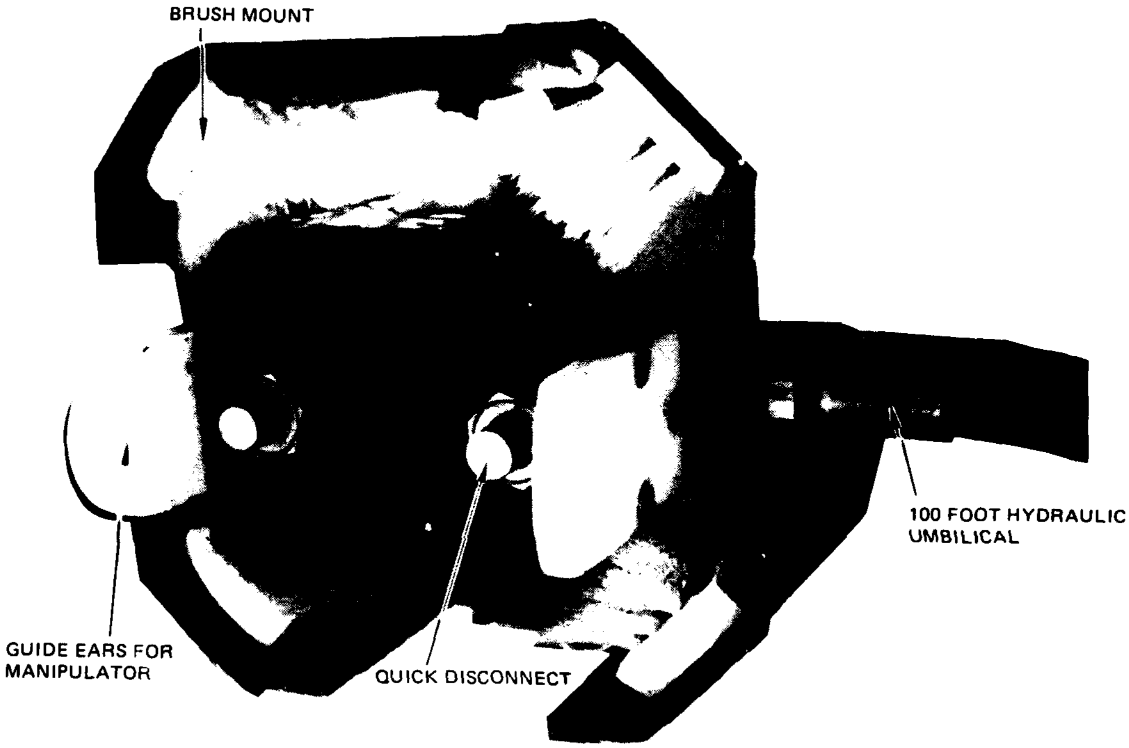

Figure D-4. Lift Module hydraulic manifold.
(LRO 5550-11-79)

APPENDIX E
RIGGING MODULE

Background

The Rigging Module (RM) (Figure E-1) was developed as a means of providing a single lift point for objects having extremely unbalanced weight distribution. The raising of an object with a high concentration of weight in a particular quadrant places excessive loads on the attachment point (ie, toggle bolt, padeye) raising the possibility of loss. The RM is an assembly which provides for an equal distribution of weight between the attachment arms eliminating excessive loading at any one point.

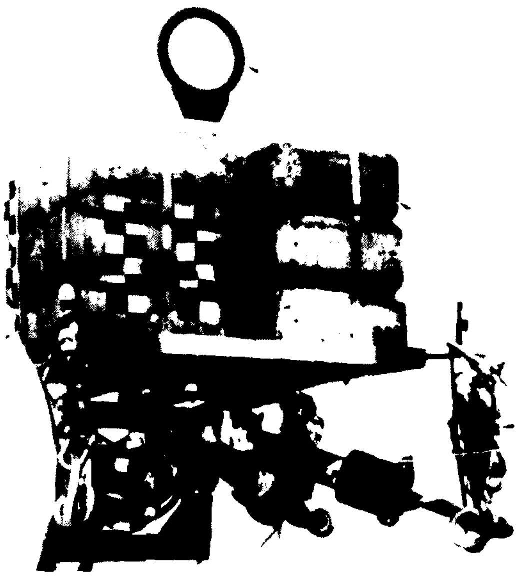

**Figure E-1. Rigging Module.
(LRO 3485-8-79B)**

The RM consists of buoyancy pods encased in a steel frame equipped with a garland ring at the top as an attachment point for the lift line. Four attachment arms extend from the underside of the frame and are equipped with load attachment lines and hooks. Each rigging line consists of a snap hook and a slackout device. Once connected to the attachment point, the line can be pulled through the "cam cleats" of the slackout device to remove the excess rigging line. Final rigging adjustments are provided automatically by each arm which is configured with a tension limiter assembly (Figure E-2) that adjusts for equal distribution of the weight of the load, on all four arms, during the lift. The tension limiter resistance force can be preset by the placement of a locking pin in one of four hole positions in each arm. Each hole position represents a different predetermined resistive force that the attachment line must exceed before it begins to slip. As the lift is begun, the attachment arm on the heavy side of the recovery object will reach its predetermined load

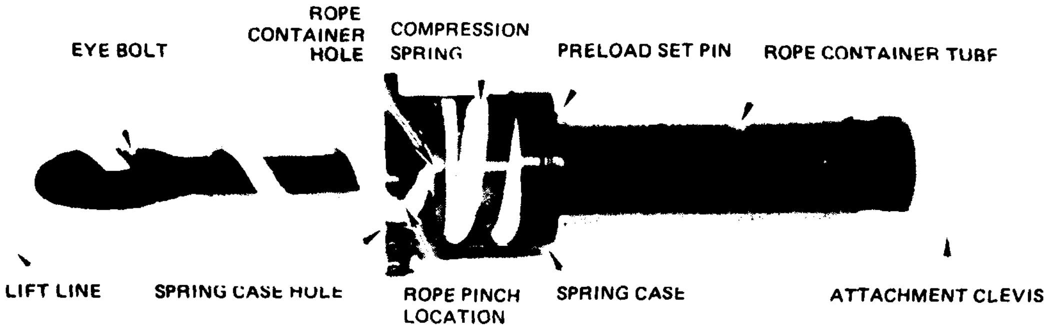

Figure E-2. Attachment Arm/Tension Limiter Assembly. (Sectioned View)
(LRO 1360-4-80B)

limit and begin to pay out line. Depending on the weight distribution on the object, three of the four tension limiter assemblies may have to slip to distribute the weight of the load on all four arms equally. At this point lift can be achieved.

Operational Scenario

The object of this test sequence was the attachment of the RM to the steel test fixture to provide a single lift point. During operations the PIV hit the test fixture turning the fixture on its side. At this time two of the four snap hooks had been attached through use of the WSP manipulator. Divers were used to connect the two remaining shackles to expedite operations. The test sequence is as follows:

1. Mate RM with WSP/PIV. The RM is mounted to the starboard side of the PIV buoyancy tanks and set to be hydraulically released. A samson line runs from the bottom of the module down the grabber arm and the snap hook/slackout device is mounted on the grabber.
2. Launch vehicle and locate target which is a steel test fixture.
3. Hover over test fixture, acquire snap hook and manipulator, attach to test fixture eye.
4. Activate hydraulic system for release of RM. Manipulator reacquires line and takes slack out of line to bring the RM close enough for the lift lines to reach attachment points on test fixture.
5. Install DTB padeyes. (For this test series, the DTB padeyes were not yet available and shackles were installed prior to launch of the RM.)
6. Manipulator used to obtain first rigging line/hook/slackout device assembly for hookup to the shackles. After hookup is completed, use manipulator to grasp slackout device and pull to adjust slack in line to be within the capability of the tension limiters.
7. Repeat sequence for all other lift points.
8. Attach lift line snap hook from vehicle to main lift point on RM.
9. Use variable ballast and/or thrusters to achieve lift.

Test Results and Observations

The RM was successfully attached to the steel test fixture and a lift conducted using the PIV thruster in conjunction with a decrease of PIV variable ballast. The following observations were made during SCI testing.

a. RM was deployed prematurely. Air trapped in hydraulic system allowed locking piston to open releasing the module.

b. Tension limiter assemblies did not deploy as the load used was too light for the attachment arm setting. Additional lift tests will be conducted in the laboratory to evaluate the equipment.

c. Operation at the slackout device by the manipulator indicated proper functioning.

APPENDIX F
LIFT SLING EMPLACEMENT DEVICE

Background

The lift sling emplacement device (Figure F-1) provides a lift method for objects, such as aircraft fuselages, which do not readily lend themselves to the installation of attachment points. This method of rigging utilizes a strap type lifting harness to provide the choke hold on the object being recovered. Difficulty arises in this task when the object to be recovered is buried in mud or sand; the lift sling assembly is intended to alleviate this problem.

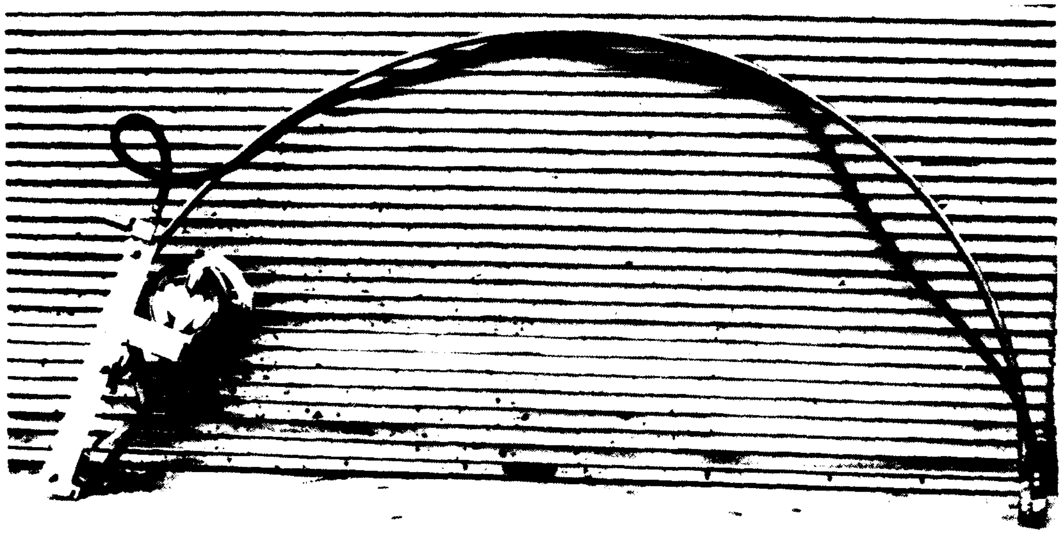

Figure F-1. Lift sling emplacement device.

The lift sling assembly consists of curved steel jetting tube supported and guided by three rollers mounted to a support frame with a 10-foot diameter semicircle (Figures F-1 and F-2). A wedge-shaped nozzle is located at one end along with provisions for attaching one loop of the synthetic sling. A 3/4-inch inside diameter hose supplies water to the opposite end of the jetting tube. The jetting tube support bracket has provisions for a quick disconnect fitting for the jetting water line (Figure F-3). A bracket was added to the female fitting of the quick disconnect to allow for holding with the manipulator of the WSP. During development it was decided that the optimum nozzle configuration was one with a small flow divider. With this nozzle configuration it was found that it was possible to advance the jetting tube and sling through the soil and if the tube stalled, waiting 20 to 30 seconds would allow the jetting water to fluidize the soil to a point where the jetting tube could be advanced further. The jetting tube support bracket has provisions for storage of the sling and choker cable, snap hook, and for grasping of the bracket with the WSP grabber arm (Figure F-4).

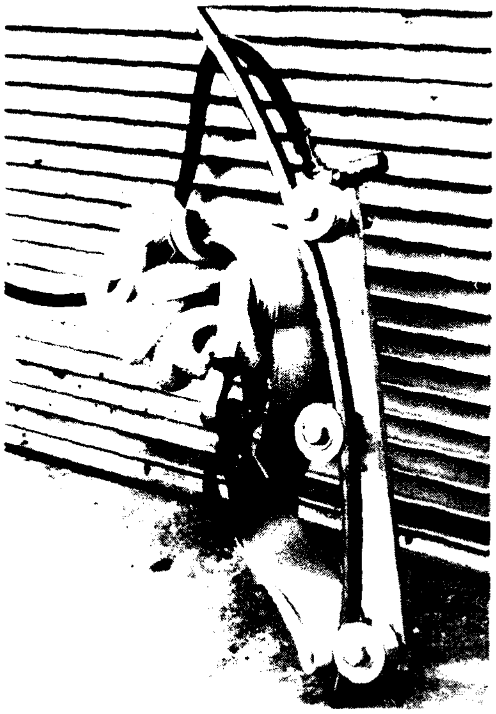

Figure F-2. Jetting tube support bracket.

Figure F-3. Jetting hose connections to jetting tube support bracket.

Figure F-4. Sling and choker cable storage.

Operational Scenario

The object of this test sequence was the installation of two sling assemblies under an F4 aircraft to demonstrate the jetting feature and for connection to a single lift point for lift of the aircraft.

1. Attach two sling assemblies to WSP toolbox at attachment brackets on slings. During actual SCI operations, only one sling assembly was taken with the vehicle at a time.
2. Launch vehicle, fly to target and position for insertion of sling.
3. Grasp the sling handle with the starboard grabber (outermost sling first) and lift the sling from the toolbox mounting bracket (Figure F-5).
4. Rotate the grabber to a forward position and retract it to within 6 inches of its stop.
5. Remove the jetting hose female quick disconnect from its storage location on the starboard grabber (align manipulator with nipple and lower grabber to separate).
6. Attach the quick disconnect to the sling (align quick disconnect halves with manipulator and retract grabber to make connection).
7. Move the sling to the insertion location and turn on the jetting water (tool pump operated) to clear a passage for the sling. Advance the jetting tube with the manipulator (using wrist motion) until fully inserted.
8. Turn off the jetting water and remove the quick disconnect from the sling and place it back on the grabber storage location.
9. Grasp the choker hook with the manipulator and pull the choker hook and line from the storage tube. Release the grabber jaws from the jetting tube support bracket and stow the grabber.
10. Transport the choker hook to the opposite end of the sling (up over the object). The hook is dropped over the F4, the vehicle flown around the F4, and the hook retrieved. This is done to eliminate pulling of the sling from under the target. During this test series, one sling (aft position) was reinstalled by divers to expedite testing after it was inadvertently pulled out by the vehicle after the first installation.
11. Insert the hook through the sling eye and cinch up the sling.
12. Connect the hook to the lift line or lift point.
13. Repeat sequence so that both slings are connected for a single point lift.
14. Use Lift Module to achieve lift.

Test Results and Observations

Overall operation of the lift sling assembly was good and a successful lift of an F4 aircraft was conducted. The following observations and modifications were made during SCI testing.

a. The jetting tube of the sling was painted white to improve visibility.

b. Reflective tape was added to the choker hook to improve visibility.

c. A longer choker line is required to ease the preciseness with which the vehicle must be maneuvered to connect the choker line following insertion of the sling assembly.

d. The variable ballast pump was used to provide the jetting and suction water during testing. There was no relief valve in series with the variable ballast pump and the jetting flow was restricted to below the pump output, causing the pump to overpressurize. This occurred during the first test of the pump causing the bursting of the graphite end plate seal. A nylon roller fertilizer pump, brought along as a backup jetting pump, was mounted to the low-speed rotary tool and mounted on the starboard grabber valve package.

e. The roller pump provided adequate jetting water for insertion, however, the low-speed motor drew enough power from the WSP hydraulic power supply to drop WSP voltage to the point that the television cameras would not work during pump operation. The PIV television cameras were used during jetting operations, however, this does not provide optimum viewing of the operations. Two relief valves have been purchased and connected in parallel to prevent overpressurizing the variable ballast pump during operations.

f. A feedback system is needed to confirm jetting system operation when the jetting nozzle is inserted underneath the aircraft and visual confirmation is not possible.

g. Operator visibility is certain to be a problem whenever the jetting action can stir up sediment. This problem did not occur during SCI testing as the bottom under the F4 was rocky.

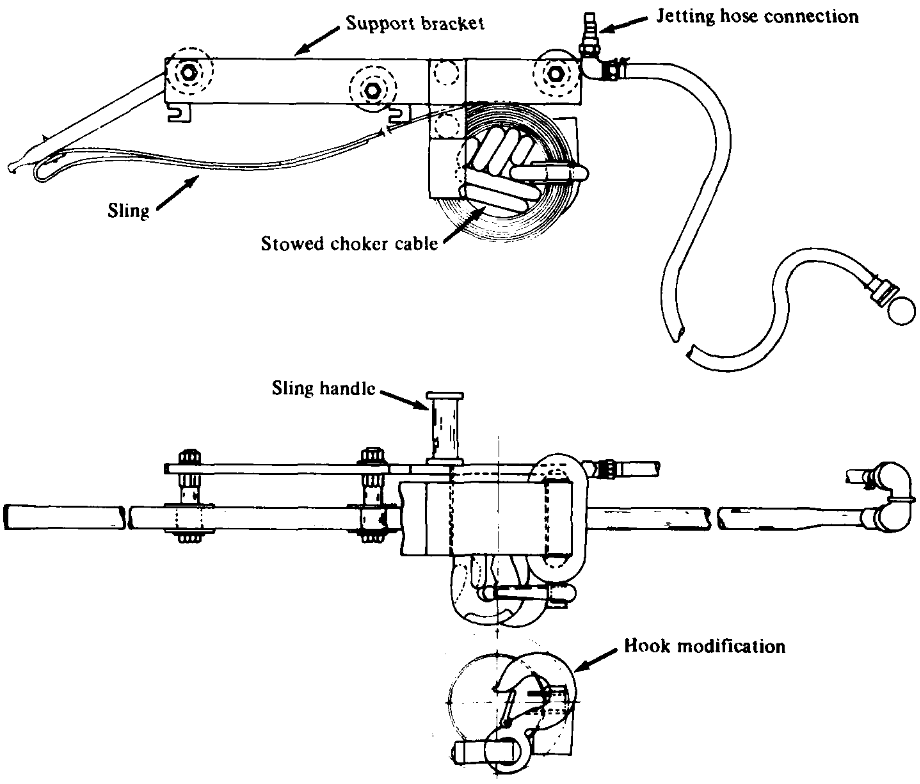

Figure F-5. Lift sling detail.

APPENDIX G
NET ASSEMBLY

Background

Development of the net assembly arose from the need to provide surface stabilization of a recovered object. The salvors require a sufficient time frame in which to secure the recovered object for towing or lifting aboard a salvage vessel and the net assembly provides a means of enclosing and holding an object without the use of conventional attachments.

The net assembly developed consists of a unit which in its stowed position measures only 4 feet wide by 20 feet long. When fully deployed the net is 20 feet by 20 feet. The net assembly frame is constructed with side members of two-inch diameter fire hose and corners made of pipe elbows and nipples connected to the fire hose. The PIV was modified with the installation of hydraulically actuated release shafts to its undercarriage. These shafts have hooks for holding of the net assembly during transit to the recovery site. A retaining canvas, with connection rings, is placed under the net assembly (in the stowed position) and then placed under the PIV (Figure G-1). The connection rings are attached to the hooks of the hydraulically actuated shafts and locked into place. The vehicle is then launched for transit.

Once at the recovery site the shafts are hydraulically actuated to release the net assembly. The vehicle is then backed off from its position over the net while laying out the fill hose. The fill hose is connected to the fire hose side member and has a quick disconnect at the WSP. Deployment of the net assembly is accomplished by filling the fire hose with sea water causing the net to unfold and the side members to become rigid (Figure G-2). Filling is achieved through use of a sea water pump powered by the WSP-operated drill motor. A pressure regulator in the system insures that the hose is not pressurized above 100 psi. When the net is fully deployed, the WSP manipulator is used to release the quick disconnect. The recovered object is then placed in the net. Each corner of the net has a connection line and ring for hookup to a single lift point. Lifting of the net and recovered object can then be accomplished through the use of the Lift Module or by PIV thruster power.

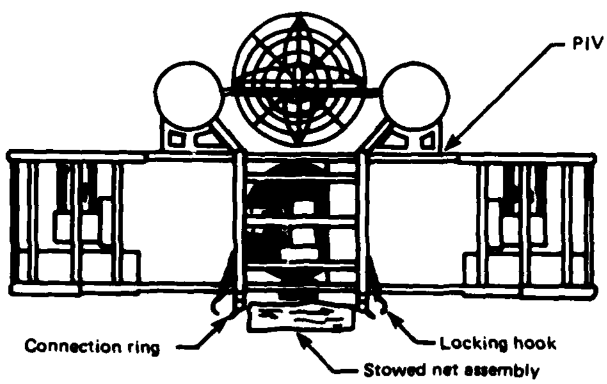

Figure G-1. Net assembly (stowed position) installed on the PIV.

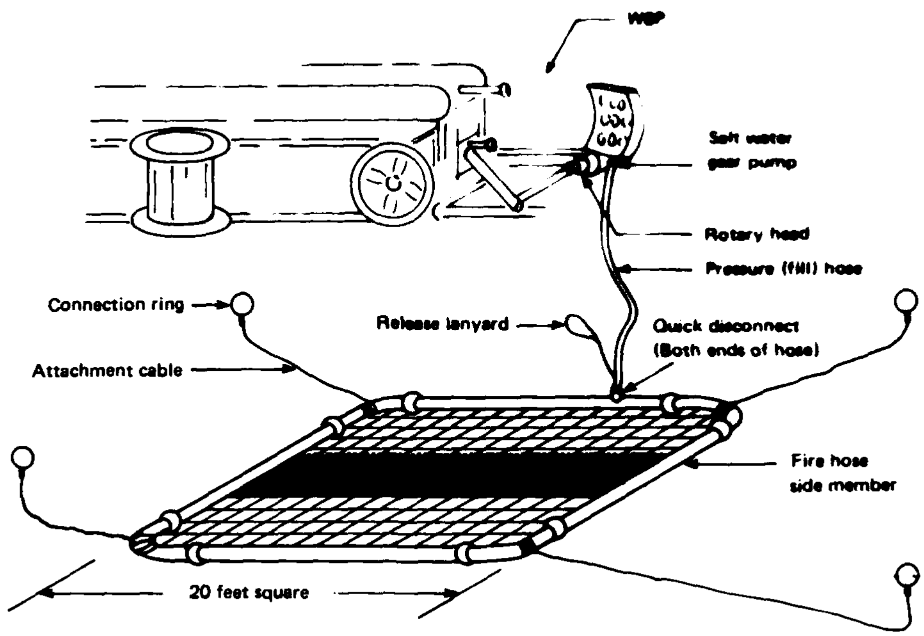

Figure G-2. Net assembly in the deployed position.

Operational Scenario

The object of this test was to demonstrate the use of the net assembly as a backup unit to an item being recovered using conventional attachments. The test sequence is as follows.

1. Secure net assembly to underside of WSP/PIV. Hydraulic actuator will release net from attachment points under vehicle.
2. Launch vehicle, locate target and land vehicle on bottom in close proximity to object. Actuate hydraulic locking shaft to release net from underside of vehicle. Divers were required to free the net from the vehicle underside when parts of the net began to float due to air entrapment.
3. Connect flex line from net to fill pump located in WSP toolbox. (Connected prior to dive to expedite operations.)
4. Fly vehicle up and back off of net with flex line faking out in front of vehicle.
5. Acquire drill motor from toolbox, insert over seawater pump, and fill hoses for net deployment.
6. Return drill motor to toolbox and press quick disconnect for release of fill hose after completion of filling procedure.
7. Position test object in net and rig the net to the Lift Module. Only partial deployment was achieved.

Test Results and Observations

Although full deployment of the net assembly was not achieved, the basic concept appears to be a viable method of transporting recovered objects to the surface for retrieval. Due to higher priority testing, only a minimum of time was available for testing of the net assembly. The following are observations made during SCI testing:

a. Problems were incurred during installation of the stowed net assembly to the undercarriage of the PIV. The weight of the net was such that the hydraulically actuated release shaft would not support the net without maintaining system pressure to prevent dropping of the net prematurely. A more positive locking method would be required in the future.

b. During transit to the test site the current was such that the net began to slide from its retaining canvas. This caused subsequent problems in releasing the net from the vehicle. Packaging requires redesign to eliminate this problem.

c. During release of the net from the PIV the net hung up on the locking arms of the shaft causing difficulty in release of the net assembly. A redesign of the release system is needed to ensure that the net falls free of the PIV. In addition, it appeared that trapped air in the fire hose was causing it to raise up under the PIV due to buoyancy.

d. Problems developed during operations to fully deploy the net assembly to the full open position. Water pressure provided by the WSP seawater pump was not of sufficient order to force open the hose at those points where there was a sharp bend. A larger diameter fire hose and stronger pump pressure could possibly resolve this problem. An alternative approach could be to design a method of using hydraulic power to force the net to the open position.

APPENDIX H
TOGGLE BOLT PADEYE

Background

The toggle bolt padeye was developed as a method of quickly and easily installing lifting points for sea-floor recovery operations. Current methods of recovering large, plate-like structures consist of using slings, grapples, or nets to capture the object to be recovered. These techniques are cumbersome, slow and frequently ineffective.

The padeye consists of a lift eye, spacer flange, grip plug, coil spring, and a key (Figure H-1). The spacer flange has small traction points which grip the plate surface and prevent the flange from rotating during deployment. The grip plug is tapered to facilitate insertion into a hole in the plate. In Figure H-1, the padeye is shown assembled in the cocked position. More than one padeye will be necessary for most recoveries and all of the holes should be drilled at the same time to minimize tool exchanges. The manipulator is used to remove a padeye from the toolbox, and insert the grip plug end into the drilled hole until the large flat of the spacer flange contacts the plate. While exerting a light force against the plate, the manipulator rotates the lift eye in either direction 180 degrees until the key aligns with a clearance groove in the spacer flange. The traction points prevent the spacer flange from rotating when the lift eye and grip plug are rotated (they are rigidly attached) during deployment. When this alignment occurs, the compression spring forces the grip plug and spacer flange together in a locked position so that they cannot rotate with respect to one another. The padeye is now in the deployed position (Figure H-3). Because the lift eye shaft is positioned eccentrically to the grip plug and the spacer flange, the 180-degree rotation results in a portion of the grip plug contacting the plate itself, providing a bearing surface against which the padeye can be pulled. The area of the bearing surface is shown in Figure H-4. Once locked, the entire assembly rotates as a unit and the bearing surface is preserved for all orientations of the eye.

Operational Scenario

The object of this test sequence was to install four padeyes to a steel test fixture for rigging to a single lift point. Due to higher priority testing only two padeyes were installed and a lift test was not conducted. The test sequence is as follows.

1. Position toggle bolt holder assembly in grabber of WSP.
2. Drill 3/4-inch hole in test object with WSP tools (Figure H-2). Predrilled holes were used to expedite operations.
3. Manipulator used to acquire toggle bolt from holder.
4. Insert toggle bolt into hole and turn padeye 180 degrees to lock toggle into position.
5. When all toggle bolts are installed a Rigging Module or other lift device could be attached to these points to provide a single point lift.

Test Results and Recommendations

Tests conducted on the toggle bolt were successful. The bolts were attached to a flat steel plate and divers confirmed they were locked. Due to time constraints a lift of the plate was not conducted.

The following observations were made during testing:

a. The toggle bolt plate requires marking to allow visual feedback for referencing of the degree of turn to deploy the unit. The zoom lens of the WSP camera was used but was not sufficient.

b. The toggle could be redesigned to incorporate a self-locking or semi-automatic mechanism.

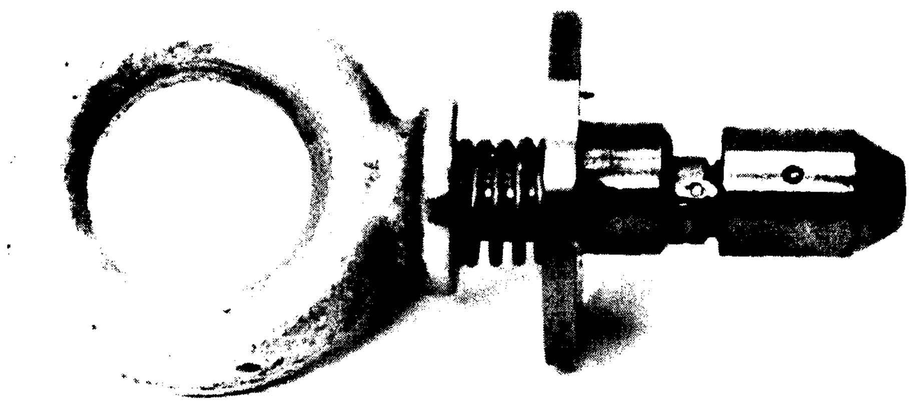

Figure H-1. Toggle bolt padeye in the cocked position for insertion. (LRO 2687-6-79B)

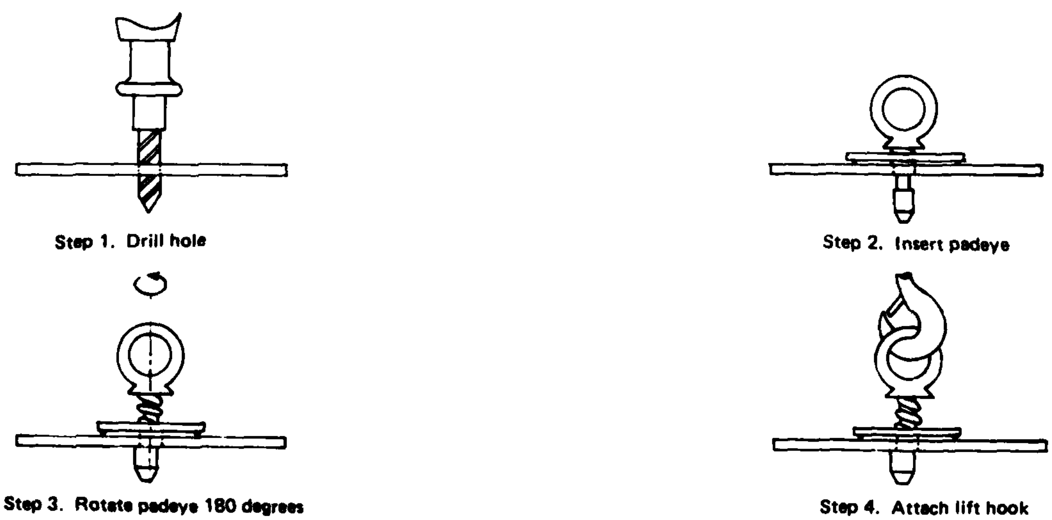

Figure H-2. Procedure for installing toggle bolt padeye.

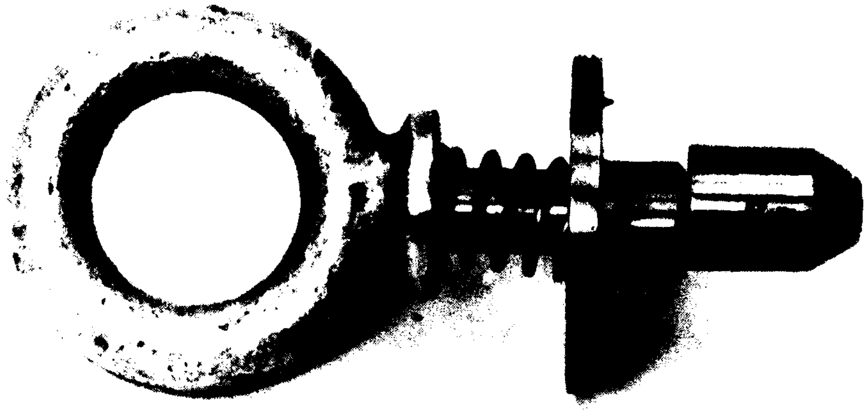

Figure H-3. Toggle bolt padeye in the deployed position.
(LRO 2688-6-79B)

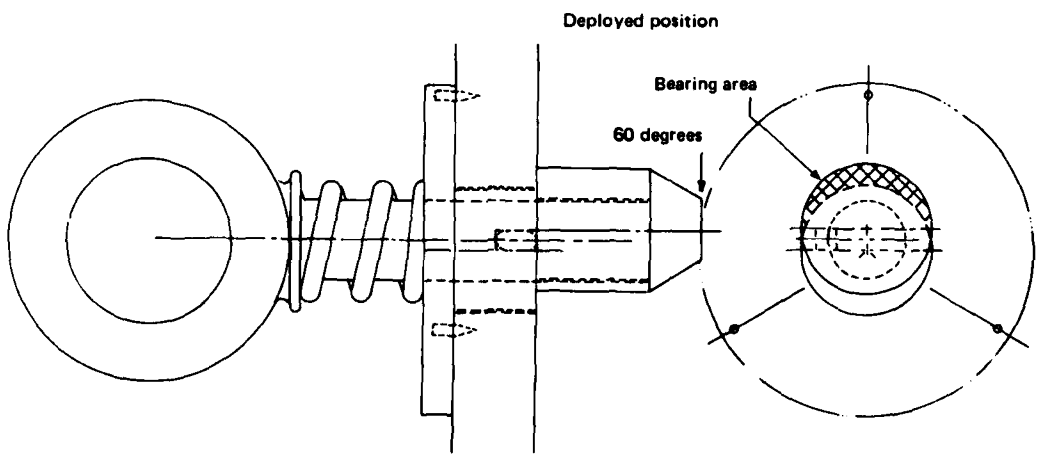

Figure H-4. Deployed toggle bolt padeye showing bearing area.

APPENDIX I
DRILL-TAP-BOLT (DTB) PADEYE

Background

The Drill-Tap-Bolt (DTB) padeye (Figures I-1a and b) was developed as an improved method of providing an attachment point for the installation of lift lines on an object which has an external structure or framework of sufficient thickness and strength for drilling, threading and bolting.

The device developed is triangular in shape with three drill-tap-bolt bits, a central lifting eye (for lift line attachment), and a suction cup (Figure I-2) for holding the unit to the object during drill-tap-bolt insertion. The unit is equipped with a holding plate capable of attachment to the WSP toolbox. Acquired by the WSP manipulator, the unit is then placed on the object to be recovered and suction applied, via suction pump attached through a quick disconnect, to a neoprene rubber seal opposite the lifting eye. With the unit now held in place the drill-tap-bolts can be inserted. Light sheet metal tabs and mild steel drill bushings provide guidance and retention for the DTBs. Silicone sealer is placed between the DTB and the guide bushing to assure that the bit cannot vibrate out during transit. The drill portion of the bit is long enough to penetrate the complete plate thickness before the tap section is engaged (Figure I-3). The tap section is long enough to produce full threads in the work piece and is followed by a chip relief section. The flutes are spiral in the drill and straight in the tap section to prevent chips from progressing up the tool and damaging the threads or impeding entrance of the bolt portion of the tool. The chip relief section is followed by a threaded bolt with a hexagonal head which serves as both the tool drive and bolt head.

Operational Scenarios

The object of this test was to install the padeye on the test fixture and rig for a single-point lift. The test sequence is as follows:

1. A set of four DTB padeyes are mounted in special clip mounts on a holding plate attached to the tool box of the WSP. Launch vehicle and dock with test object.
2. Attach the quick disconnect end of the suction hose to the DTB by pushing onto the nipple using the manipulator. The first will be attached prior to launch to expedite operations.
3. Manipulator is used to remove DTB padeye by pulling out and then sliding up to complete removal from the clips and channel of the holder.
4. Hold the DTB in the place of attachment with the manipulator, turn on suction pump, and pull slightly on DTB to ensure suction is sufficient to hold in place.
5. Remove manipulator from DTB padeye and acquire impact wrench with 5/8 inch socket. Insert socket over tap bolt and insert all three tap bolts in a clockwise direction.
6. Return tool to tool box, remove suction line and attach to next DTB in holder. Repeat sequences for remaining three DTB padeyes.
7. Rig to padeyes for lift.

Test Results and Observations

Due to the priority of other tests, this device was not used during actual SCI testing. The unit was tested on board the YD197 to check the holding capability of the suction cup. The unit was placed against a flat steel plate, immersed in a bucket of water and the suction pump engaged. During this test the impeller rotation was reversed causing a pressure increase (vice vacuum) causing the pump's carbon face plate to blow out. There was no replacement available and therefore no further onboard testing was conducted.

The following observations were made while at SCI:

a. The drill-tap-bolt bits used may be too brittle for actual operations (due to fabrication error).

b. The drill-tap-bolt bits need to be painted for improved visibility when using vehicle cameras for viewing.

c. A guide to assist in coupling of the quick disconnect for suction was added during the tests to assist the operator in alignment.

d. A relief valve needs to be installed in the suction pump line to eliminate possibility of pressurization. As a temporary fix, a separate pump was added to the PIV during the sea tests but was not actually used.

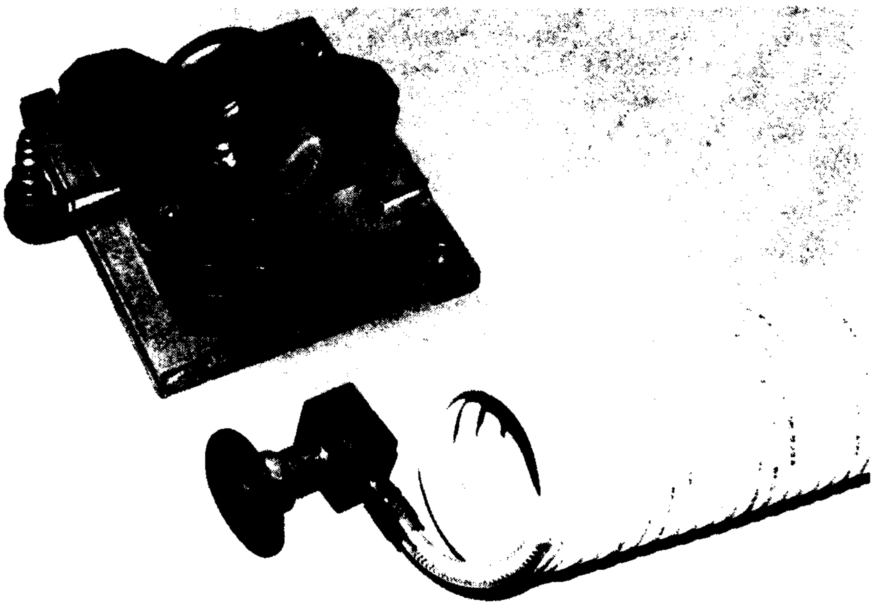

Figure I-1a. DTB padeye mounted in its holding plate and the suction hose and quick disconnect fitting.

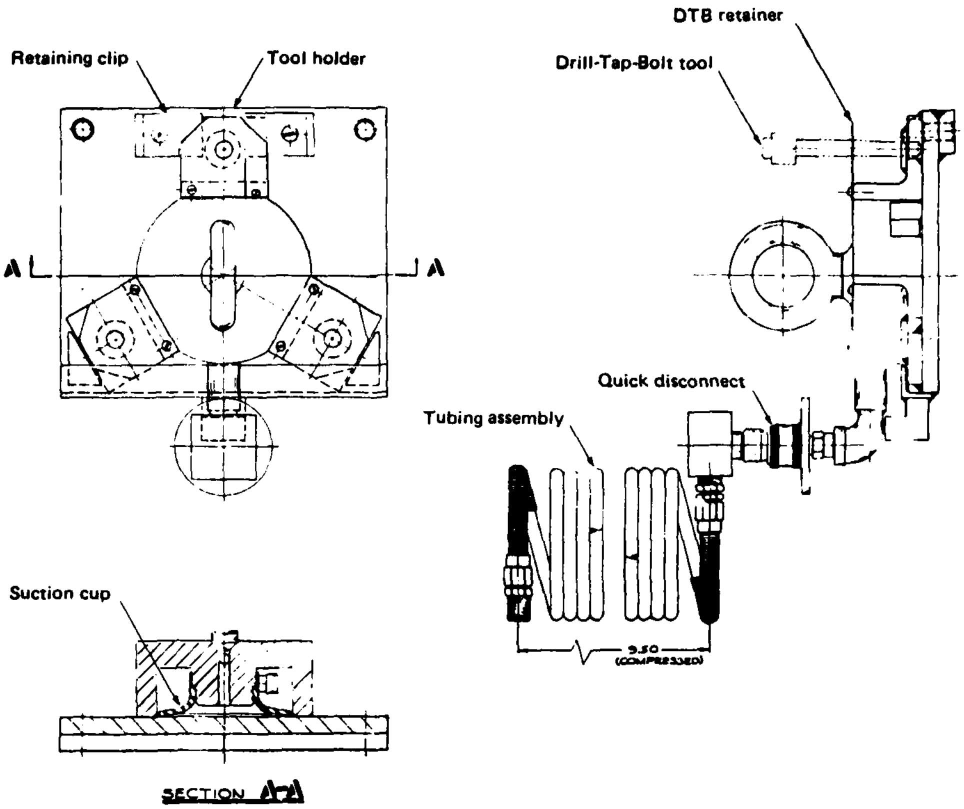

Figure I-1b. DTB schematic.

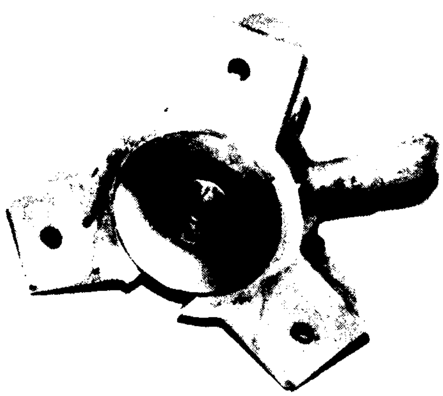

Figure I-2. DTB padeye, bottom view.

Figure I-3. DTB tool bit.

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