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Naval Ocean Systems Center Underwater Vehicle History

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NAVAL OCEAN SYSTEMS CENTER
San Diego, California 92152-5000

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ADMINISTRATIVE INFORMATION

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The development, past and present, of remotely operated and autonomous unmanned undersea vehicles (ROVs and AUVs) at the Naval Ocean Systems Center is summarized and vehicle characteristics listed. The ongoing work is described in detail.

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INTRODUCTION

As the lead Navy laboratory in ocean engineering, NOSC has as one of its principal responsibilities the development of unmanned vehicle systems needed by the Navy to perform Fleet missions to all ocean depths. The systems used for this are Remotely Operated Vehicles (ROVs) and Autonomous Unmanned Vehicles (AUVs)—jointly called Unmanned Undersea Vehicles (UUVs). In the pursuit of these missions for nearly 3 decades, NOSC has become the lead Navy laboratory in the area of UUVs, developing 21 systems in-house, including mine neutralization vehicles, complex work systems, autonomous search systems, and vehicles to support the NASA Space Shuttle program. A summary of these systems is provided in Table 1. These ROVs and AUVs have been developed for such host platforms as submarines, aircraft (helicopters), and surface ships. A natural result of this R&D has been the development of a substantial technology base in control systems, communication links (acoustic and fiber optics), materials (ceramics and composites), advanced energy sources, navigation, sensors, manipulators, and work systems. This vast experience has provided the Navy with an unparalleled system capability for large or small vehicles with operating depths from shallow water to the deep ocean. Through constant interaction with the Fleet, this capability is matched by an operational understanding of tactical capabilities and limitations of UUVs.

This report provides a summary of vehicles previously developed at NOSC along with those that are presently undergoing development at the Center. The ongoing work is discussed in more detail at the beginning of this historical account in order to provide a better understanding of the Center's capabilities in this critical area. For completeness, past developments in the area of manned submersibles have also been included.

HISTORY

Organizations that preceded NOSC pioneered important work in ocean engineering. For example, Naval Electronics Laboratory (NEL) concentrated on supporting the early generation of manned submersibles (TRIESTE and DEEPSTAR), while Naval Ordnance Test Station (NOTS) was concerned with operating underwater missile ranges off Long Beach and San Clemente Island. NOSC's involvement in ocean engineering, described in the following paragraphs, stemmed from these activities.

During the early 1960s, NOTS engineers developed the Navy's first ROV, the Cable-Controlled Underwater Recovery Vehicle (CURV), which, by 1965, could retrieve sunken ordnance from depths of 800 ft. CURV, a surface-powered, cable-controlled, underwater system that integrated TV, sonar, still cameras, and a variety of manipulators and grabbers, successfully validated the concept of an underwater work system. Successive versions of CURV could reach even greater depths (ultimately, 10,000 ft) and perform additional, more complex missions. Due to its air-transportability, CURV I was used to recover the H-bomb lost off Palomares, Spain, in 1966; and CURV III was used to rescue the operators of the bottomed PISCES IV manned submersible off Ireland in 1973. NOSC supported CURV III for the Supervisor of Salvage until FY 85, when the system became part of the salvage equipment pool. Presently, NOSC operates a modernized CURV II to recover expended test ordnance in the San Diego/San Clemente Island area.

NOSC engineers in Hawaii have pursued extending cable-powered ROV work systems for deep-ocean operations. Initial work on the Remote Unmanned Work System (RUWS) began in 1968, culminating in a series of successful demonstration dives in the mid-1970s. This initial work required advances in cables, connectors, work systems, and teleoperator and telemetry technology and was followed by the present-day Advance Tethered Vehicle (ATV) development. During 1985, the ATV completed a series of test dives off Hawaii, reaching

Table 1. Chronological history of NOSC vehicle development.

MANNED VEHICLES	YEAR COMPLETED
MORAY	1964
DEEP JEEP	1964
HIKINO	1966
BTV	1970
DEEP VIEW	1971
MAKAKAI	1971
REMOTELY OPERATED VEHICLES (ROVs)	
CURV I	1965
CURV IIA	1967
CURV IIB	1968
CURV IIIA	1969
CURV IIIB	1971
CURV IIIC	1971
SNOOPY	1972
SCAT I	1973
ELECTRIC SNOOPY	1974
NAVFAC SNOOPY	1975
RUWS	1975
MNV	1977
FOCUS	1978
NOZZLE PLUG	1979
CURV II C	1980
SCAT II	1984
ATV	1989
AUTONOMOUS UNDERWATER VEHICLES (AUVs)	
FS I	1978
AUSS	1983
FS II	1983
FS-MNV	1989

depths of 12,000 ft. The ATV system is considerably lighter than the RUWS and can be transported by C-130 aircraft. The initial cable developed for RUWS, which itself was a breakthrough development in using Kevlar as a strength member, has been exploited in the development of the new ATV cable, which incorporates fiber-optic elements for transmitting data and command and control signals. Unlike RUWS, which was used strictly as a test-bed, the ATV will be further developed and tested and will become operational in the Fleet during 1989/1990.

Concurrent with the development of RUWS, NOSC pioneered the development of a series of small, light work and inspection vehicles for use in shallow waters. These vehicles were needed for simpler, shallower tasks, for which the large CURV/RUWS type machines proved too cumbersome or expensive.

The SNOOPY series of small ROVs started in 1970 with the original SNOOPY, essentially a swimming TV camera that could dive to 200 ft and inspect and recover small objects. Subsequently, the more capable Electric SNOOPY could operate to 1500 ft; and finally, NAVFAC SNOOPY, completed in 1978, included a small scanning sonar system and was delivered to the Naval Facilities Engineering Command for use in their construction work.

In 1971, NOSC demonstrated with CURV and SNOOPY that a cable-controlled vehicle could be used for mine inspection and neutralization. Commencing in 1972, NOSC engineers designed and built, in-house, the Advanced Development Model (ADM) of the Mine Neutralization System (MNS). This effort culminated in 1977 with the successful completion of deep-water OPASSIST testing from a Fleet minesweeper (USS PLUCK) off St. Croix, VI. The ADM design data, together with valuable at-sea experience, was incorporated into a NAVSEA procurement package for the ensuing competitively procured Engineering Development Model (EDM). NOSC was named Technical Direction Agent to oversee the contractors. TECH/OPEVAL was successfully completed in 1982, and a production contract was awarded a year later. Presently, 14 systems (including 27 vehicles) of this unique, militarized ROV system are being delivered for installation on all of the new-class mine-countermeasures ships (MCM and MHC).

NOSC recognized in the mid to late 1970s that surface-powered ROVs had limitations caused by the cable itself. The newly emerging artificial intelligence and robotics technologies, coupled with advances in component miniaturization, led to the development of free-swimming ROVs, also known as Autonomous Unmanned Vehicles (AUVs). The Experimental Autonomous Vehicle (EAVE) West, developed originally as a shallow-water test-bed for the Mineral Management Service (formerly part of the U.S. Geological Survey) is now a test-bed for Navy projects and is known as the Free Swimmer (FS). This AUV is used to investigate advanced communications links (e.g., expendable fiber-optic microcable); onboard computer architectures aimed at providing autonomy; mechanical configurations; and incorporation of state-of-the-art sensors.

As a companion system to the ATV, NOSC is developing the Advanced Unmanned Search System (AUSS). This unique, acoustically controlled free-swimming vehicle system will search the deep-ocean sea floor and, perhaps, someday replace the heavier and slower surface-towed search systems. This advanced-technology AUSS is undergoing extensive at-sea testing and, if proven successful, will become operational in the early 1990s.

In addition to the AUV systems development just discussed, significant contributions have been made by NOSC scientists and engineers in related technologies, as evidenced by the many patents they hold. Some noteworthy examples include head-coupled TV; stereo-TV; hydraulic and electric-drive manipulators; cable-cutters and other tools; fiber-optic microcable and winding techniques; pressure-resistant optical connectors; acoustic underwater communication links; oil-filled cable harnesses· launch and recovery systems; Kevlar used as a cable strength member; graphite composite and ceramic housings; supervisory-controlled computer architectures; and sensors for acoustic links.

TRANSITION

For nearly 30 years, NOSC has pursued the development of a variety of unmanned undersea vehicles. Throughout this period, considerable effort has been devoted to ensuring timely technology transfer to industry and academia. Industry incorporated much of the early work on the heavy work vehicles into systems designed for offshore oil field support (e.g., oil-filled cable assemblies, tether management, vehicle layout, and so on). Likewise, the burgeoning commercial unmanned vehicle industry has incorporated the Kevlar and fiber-optic-cable technology and remote presence systems pioneered by the Center. And of course, successfully completing the ADM of the MNS resulted in the total disclosure of the NOSC design for the succeeding competitive procurement of the EDMs and present-day production system. Today's proliferation of smaller vehicles also had its beginnings at the Center, and it is anticipated that much of the current work on ATV, AUSS, and FS will also be adopted by industry. Close technical liaison with United States and foreign vehicle developers is maintained by active involvement and leadership in several technical societies. This ensures maximum data exchange and enables NOSC engineers and scientists to remain current in this rapidly evolving area.

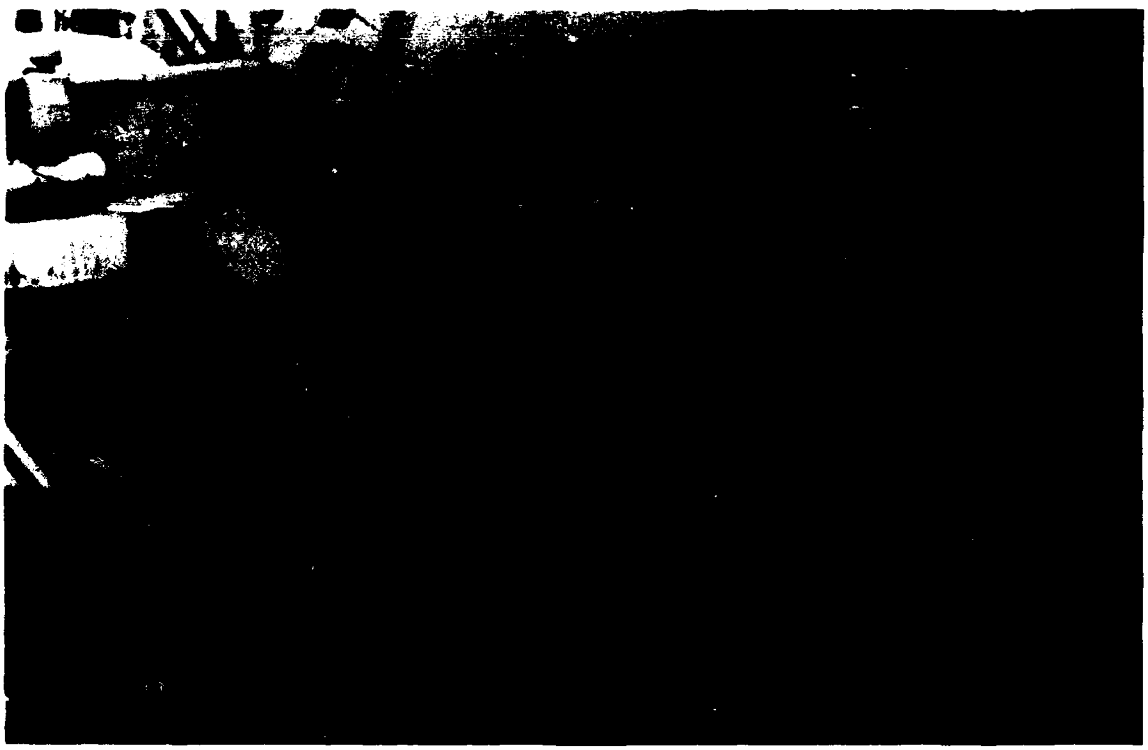
CONCLUSION

NOSC is the largest Navy laboratory group engaged in ROV/AUV development, test, and evaluation. NOSC's commitment to continuing "hands-on" ocean engineering development assignments, through in-house and DOD sponsor funding, assures the Navy of continued support in its goal of introducing UUVs into Fleet missions in the future.

1 MANNED VEHICLES

1.1 MORAY

Vehicle Name:	Moray
Type/Purpose:	Two-man submersible/prototype of submarine-launched "Attack Submersible"
Initial Operation:	1964
Depth:	Tested to 2,000 ft, designed to 6,000 ft
Speed:	15 knots
Weight in Air:	11,000 lb
Dimensions:	33′ × 66″ (L × D)
Power Requirements:	Ag-Zn or lead-acid batteries
Propulsion:	150-hp electric motor with counter rotating props
Instrumentation:	Depth, pitch and roll, TV camera, radio communication equipment
Navigation:	Compass, CTFM sonar
Other:	Project initiated at NOTS, China Lake; separate personnel and equipment pressure spheres



1.2 DEEP JEEP

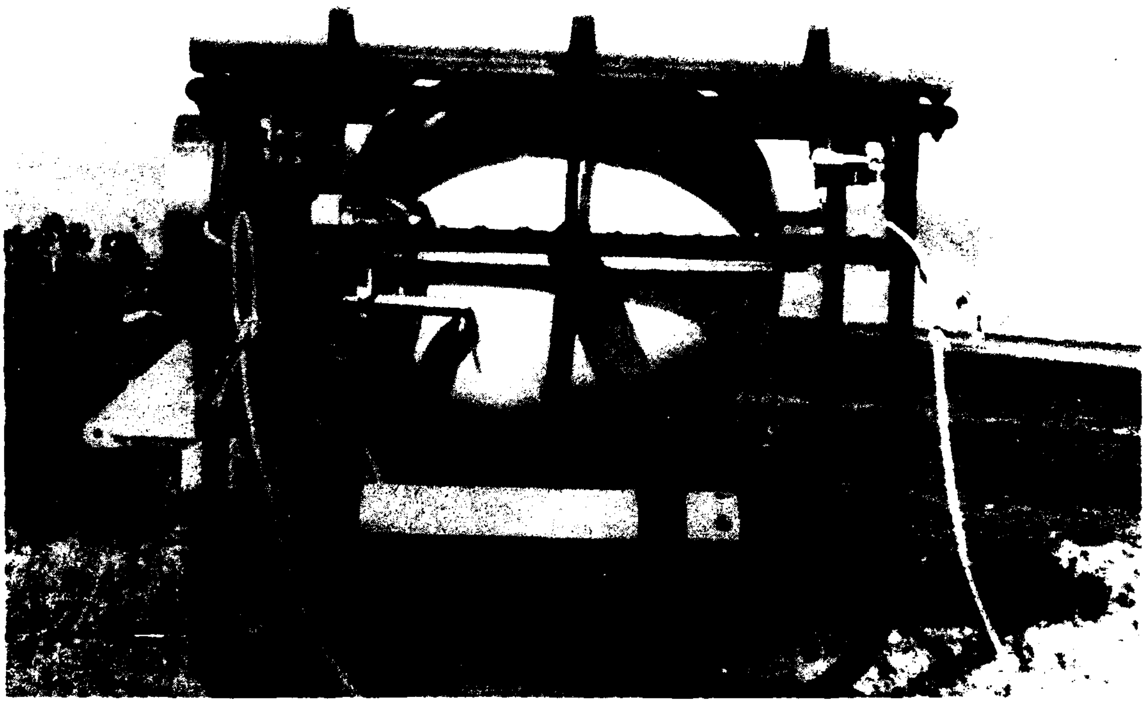
Vehicle Name:	Deep Jeep
Type/Purpose:	Manned submersible/research
Initial Operation:	1964
Depth:	2,000 ft
Speed:	1-2 knots
Weight in Air:	8,000 lb
Dimensions:	10′ × 8.5′ × 8′ (L × W × H)
Power Requirements:	Eight 6-V lead-acid batteries, 7 kWh
Propulsion:	Two electric thrusters
Instrumentation:	Underwater telephone, avoidance sonars
Navigation:	Depthometer, compass
Other:	Project initiated at NOTS, China Lake

1.3 HIKINO

Vehicle Name:	Hikino
Type/Purpose:	Two-man submersible/research
Initial Operation:	1966
Depth:	20 ft
Speed:	1-3 knots
Weight in Air:	5,700 lb
Dimensions:	16′ × 8′ × 5′ (L × W × H)
Power Requirements:	Twenty 6-V 190-Ah lead-acid batteries
Propulsion:	Two cycloidal propellers, 1.4-hp DC motors
Instrumentation:	NA
Navigation:	Visual
Other:	Project initiated at China Lake NOTS

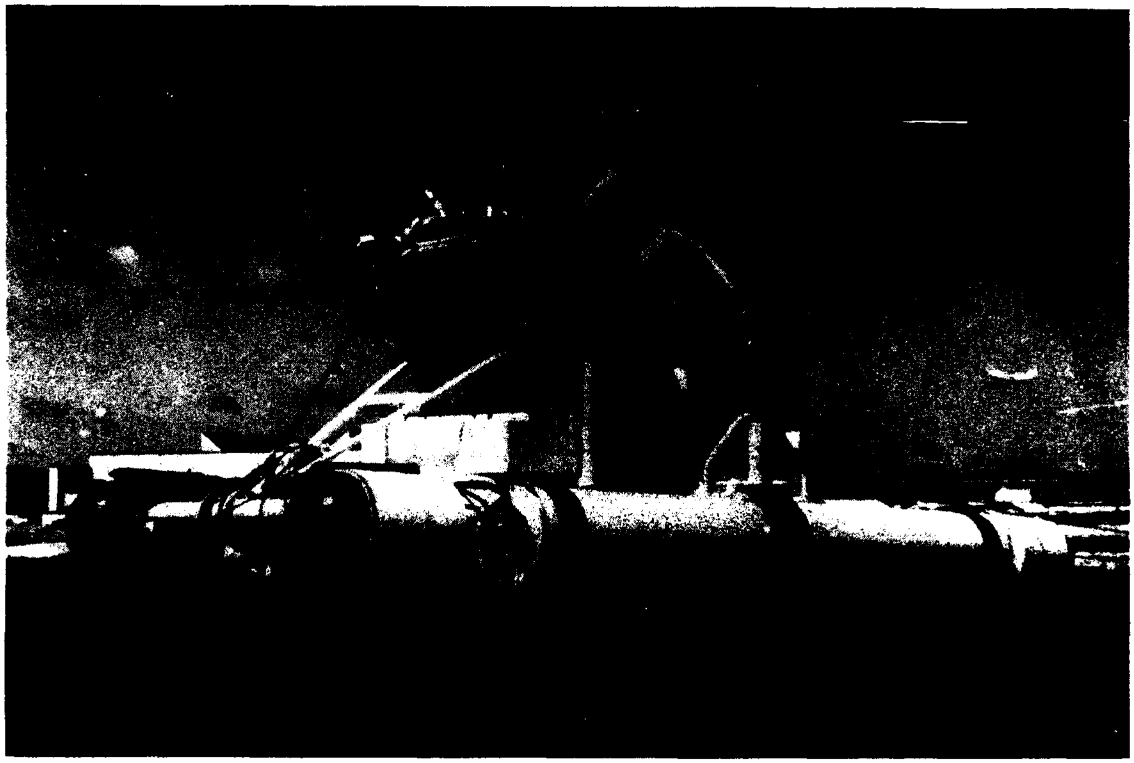
1.4 BTV

Vehicle Name:	Buoyancy Transport Vehicle (BTV)
Type/ Purpose:	Free-swimming diver-operated underwater vehicle/ provides lift and transport capability for underwater loads up to 1,100 lb.
Initial Operation:	1970
Depth:	850 ft
Speed:	3 knots
Weight in Air:	650 lb
Dimensions:	6′ × 4′ × 4′ (L × W × H)
Power Requirements:	6-kW Ag-Zn batteries
Propulsion:	Specially designed electrohydraulic propulsion system powering four screw propellers
Instrumentation:	Battery level, load indication
Navigation:	Diver-controlled three-dimensional positioning
Other:	Hydraulic outlets provided for operation of hydraulic power tools from system power.



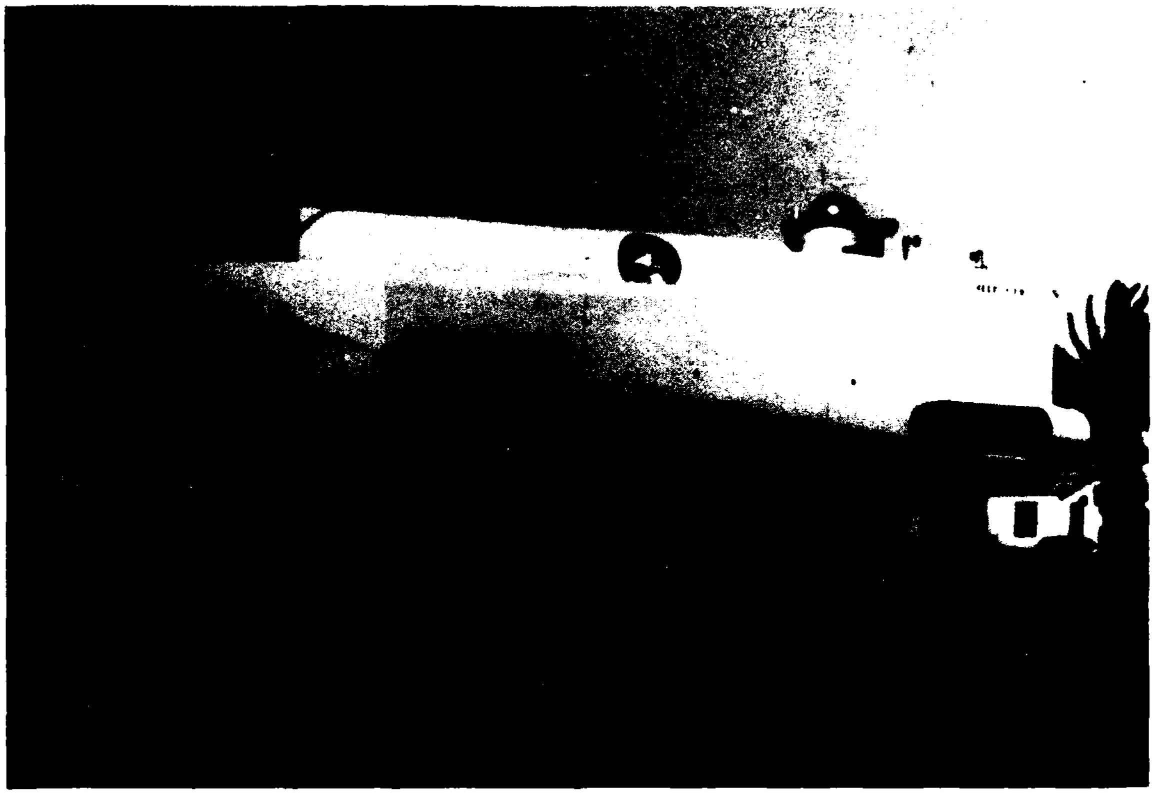
1.5 MAKAKAI

Vehicle Name:	Makakai
Type/Purpose:	Two-man submersible/research
Initial Operation:	1971
Depth:	600 ft
Speed:	1 knot, 3-knot burst
Weight in Air:	10,600 lb
Dimensions:	18.5′ × 8′ × 7.5′ (L × W × H)
Power Requirements:	120-V, 36-kWh lead-acid batteries, 8-hour endurance
Propulsion:	Two hydraulic cycloidal-thrusters
Instrumentation:	Underwater telephone, 2 depthometers, altimeter
Navigation:	Compass
Other:	Spherical acrylic hull, 4 degrees of motion freedom



1.6 DEEP VIEW

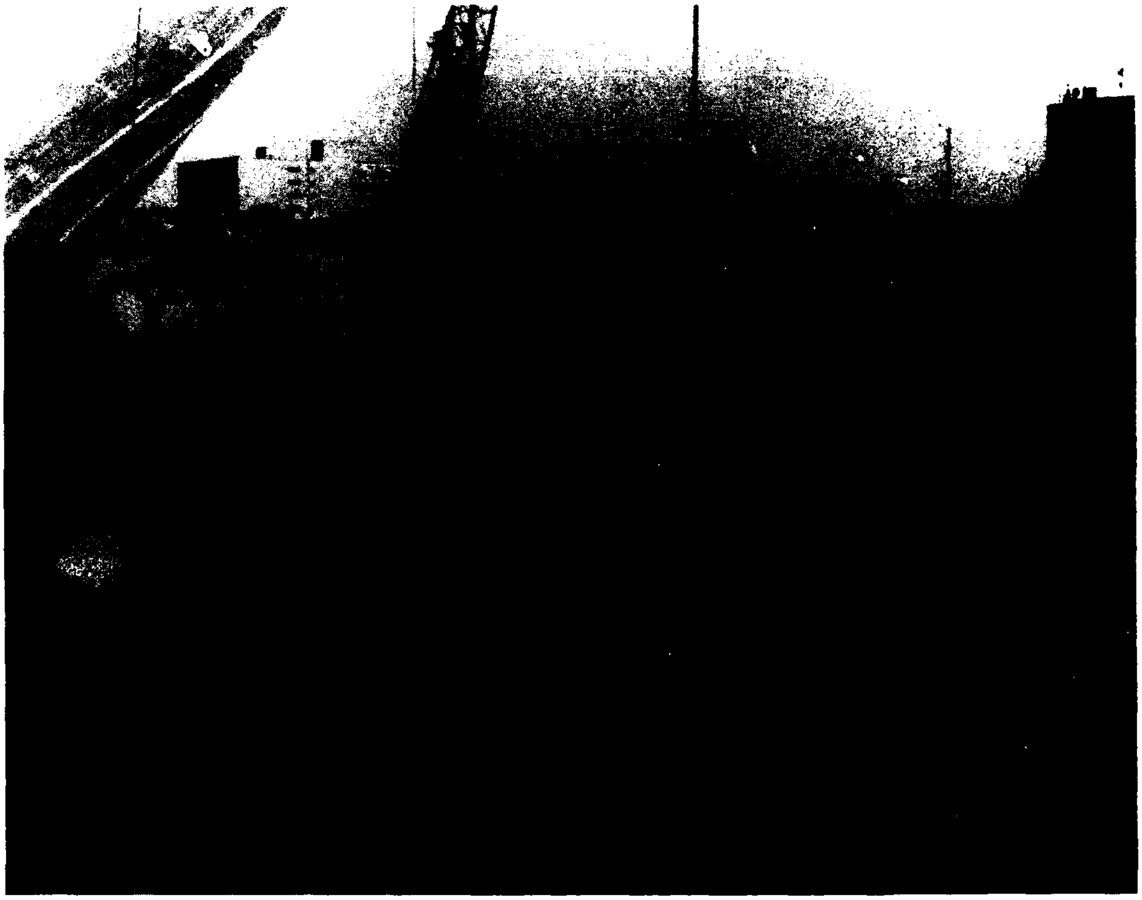
Vehicle Name:	Deep View
Type/Purpose:	Two-man submersible/research
Initial Operation:	1971
Depth:	600 ft
Speed:	1-5 knots
Weight in Air:	12,000 lb
Dimensions:	16.5′ × 6.1′ × 7.5′ (L × W × H)
Power Requirements:	Sixteen 6-V, 100-A lead-acid batteries
Propulsion:	Five 5-hp electric motors, 2 stern and vertical, 1 lateral
Instrumentation:	Underwater telephone, UHF, sound-powered phone
Navigation:	Compass
Other:	Transparent glass bow



2 REMOTELY OPERATED VEHICLES (ROV)

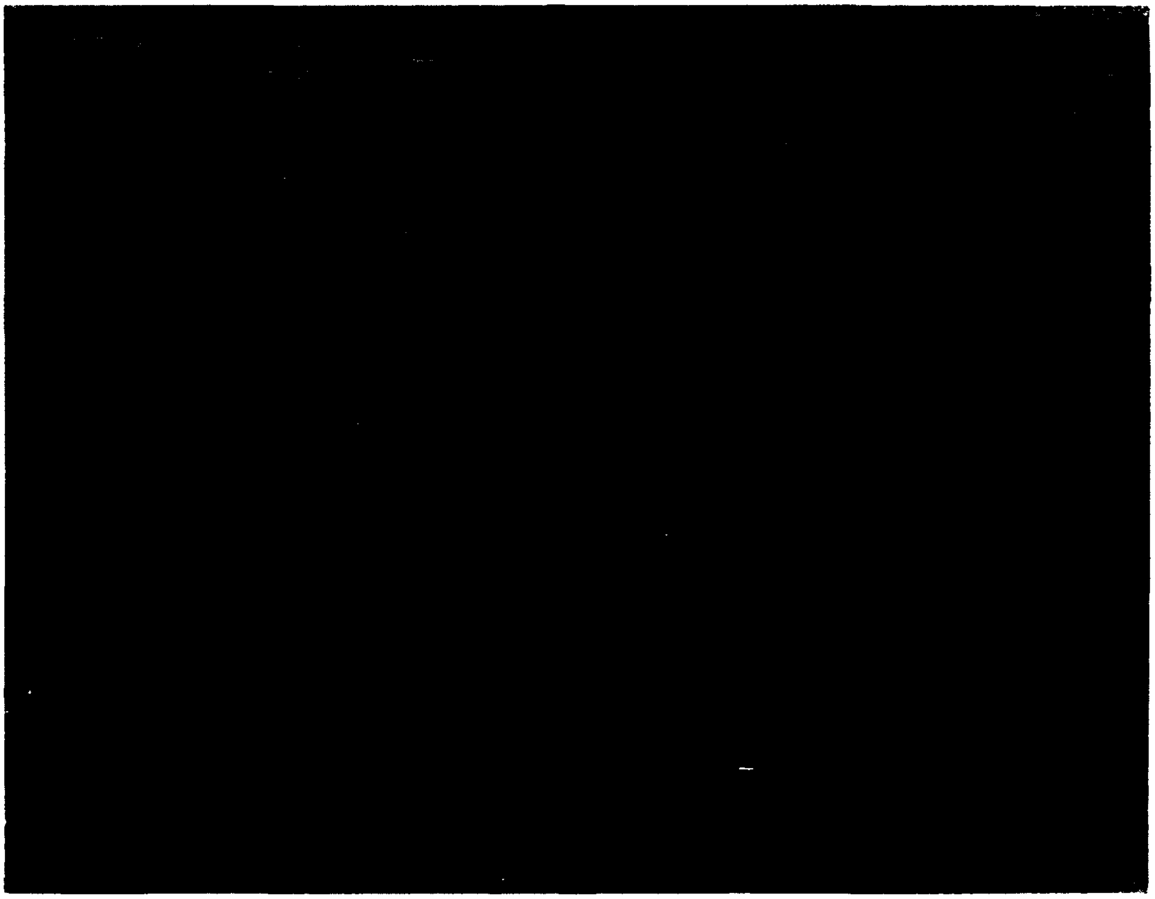
2.1 CURV I

Vehicle Name:	Cable-Controlled Underwater Recovery Vehicle (CURV I)
Type/Purpose:	ROV/torpedo recovery
Initial Operation:	1965
Depth:	2,000 ft (extended to 3,000 ft)
Speed:	4 knots
Weight in Air:	2,500 lb
Dimensions:	15′ × 6′ × 6′ (L × W × H)
Power Requirements:	440 VAC, 3 phase, 60 Hz, 50 kW via tether
Propulsion:	Three 10-hp electric thrusters
Instrumentation:	TV camera, still camera, lights, altimeter, Straza 500 sonar (CTFM), manipulator, depthometer
Navigation:	Flux gate compass, altimeter, bottom-mounted transponder
Other:	Used in atomic bomb recovery in Spain 1966; first Navy-developed ROV



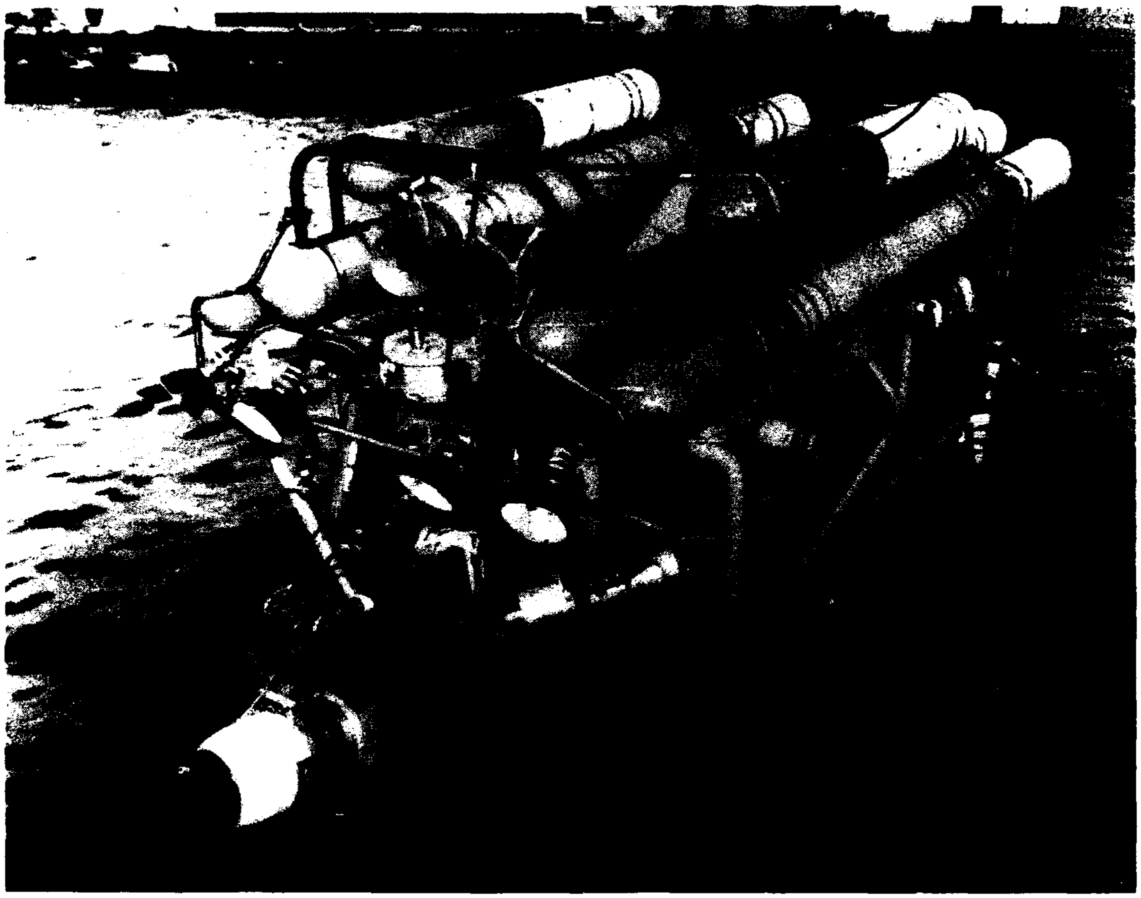
2.2 CURV IIA

Vehicle Name:	Cable-Controlled Underwater Recovery Vehicle (CURV IIA)
Type/Purpose:	ROV/torpedo recovery
Initial Operation:	1967
Depth:	2,500 ft
Speed:	4 knots
Weight in Air:	3,450 lb
Dimensions:	15′ × 6′ × 6′ (L × W × H)
Power Requirements:	440 VAC, 3 phase, 50 kW via tether
Propulsion:	Three 10-hp electric motors
Instrumentation:	Two TV cameras, 35 mm still camera, lights, altimeter, depthometer, active and passive sonar, manipulator
Navigation:	Flux gate compass, bottom transponder
Other:	Second vehicle built for NUWES, Keyport, Washington



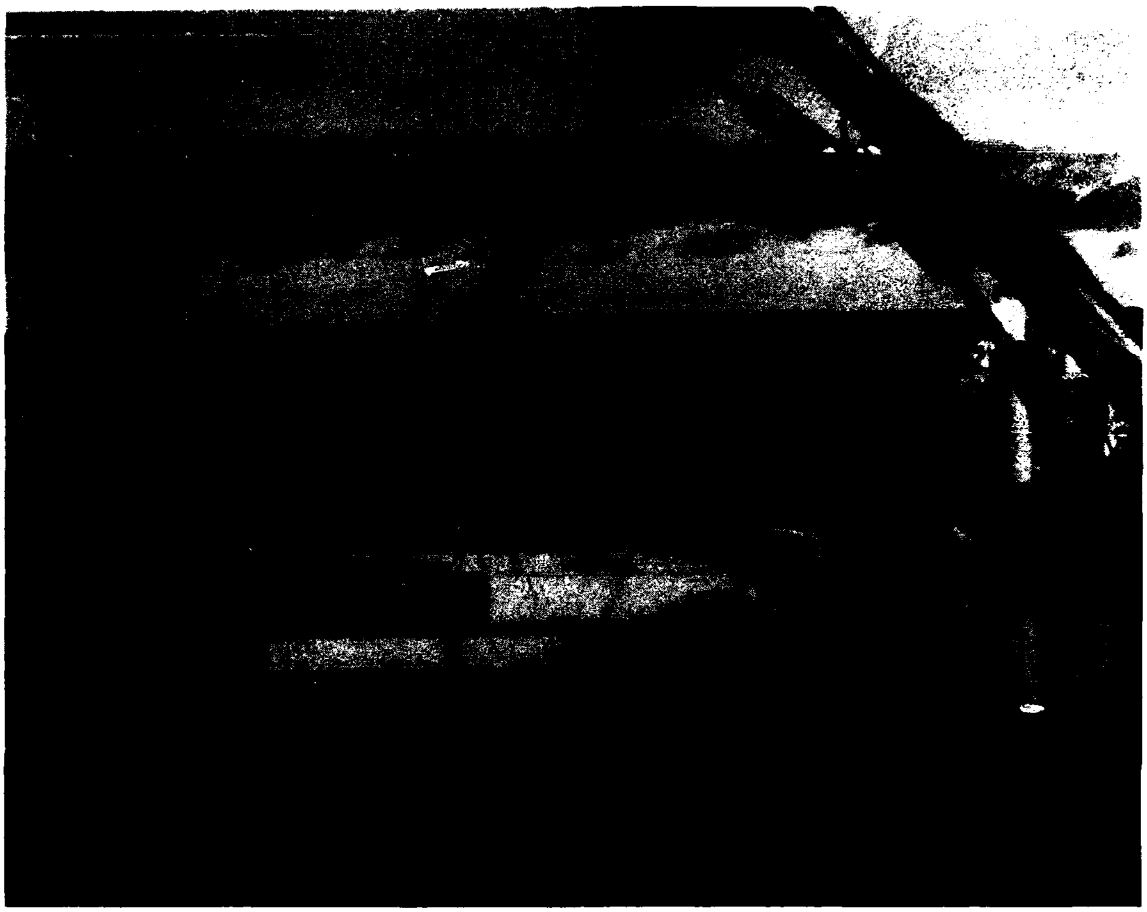
2.3 CURV IIB

Vehicle Name:	Cable-Controlled Underwater Recovery Vehicle (CURV IIB)
Type/Purpose:	ROV/torpedo recovery
Initial Operation:	1968
Depth:	2,460 ft
Speed:	4 knots
Weight in Air:	7,000 lb (estimated)
Dimensions:	15′ × 6′ × 6′ (L × W × H)
Power Requirements:	440 VAC, 3 phase, 50 kW via tether
Propulsion:	Three 10-hp electric motors
Instrumentation:	Two TV cameras, 35 mm still camera, lights, altimeter, depthometer, active and passive sonar, manipulator
Navigation:	Flux gate compass, bottom transponder
Other:	



2.4 CURV IIC

Vehicle Name:	Cable-Controlled Underwater Recovery Vehicle (CURV IIC)
Type/Purpose:	ROV/torpedo recovery
Initial Operation:	1980
Depth:	6,000 ft
Speed:	4 knots
Weight in Air:	6,900 lb
Dimensions:	18′ × 6′ × 6′ (L × W × H)
Power Requirements:	440 VAC, 3 phase, 50 kW via tether
Propulsion:	Three 10-hp electric motors
Instrumentation:	Two TV cameras, 35 mm still camera, 16 mm movie camera, lights, altimeter, depthometer, active and passive sonar, manipulator
Navigation:	Flux gate compass, boat-mounted acoustic locating device
Other:	

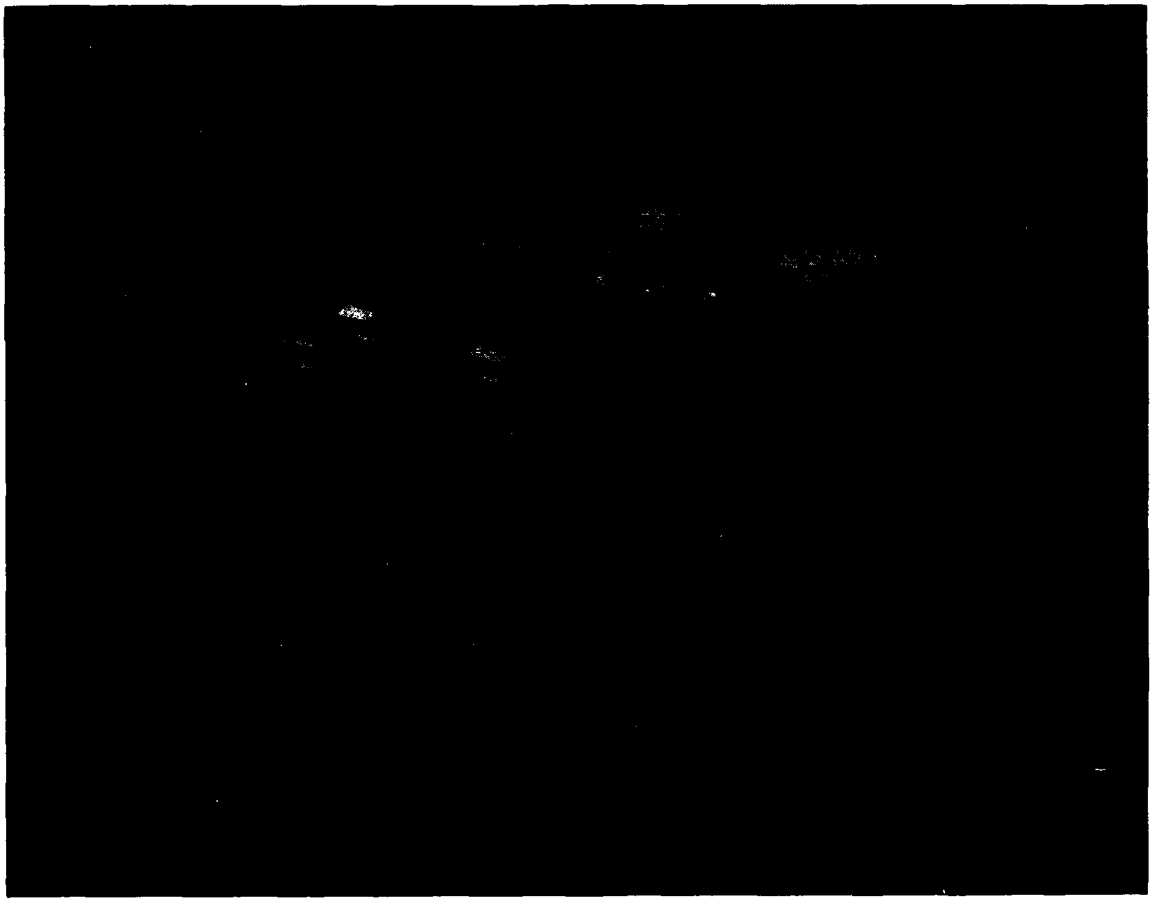


2.5 CURV IIIA

Vehicle Name:	Cable-Controlled Underwater Recovery Vehicle (CURV IIIA)
Type/Purpose:	ROV/torpedo recovery
Initial Operation:	1969
Depth:	6,500 ft
Speed:	4 knots
Weight in Air:	4,000 lb
Dimensions:	15′ × 6.5′ × 6.5′ (L × W × H)
Power Requirements:	440 VAC, 3 phase, 50 kW via tether
Propulsion:	Three 10-hp electric motors
Instrumentation:	Two TV cameras, 35 mm still camera, lights, altimeter, depthometer, active and passive sonar, manipulator
Navigation:	Magnetic compass, boat-mounted acoustic location device
Other:	Tubular aluminum frame, glass sphere and syntactic foam buoyancy

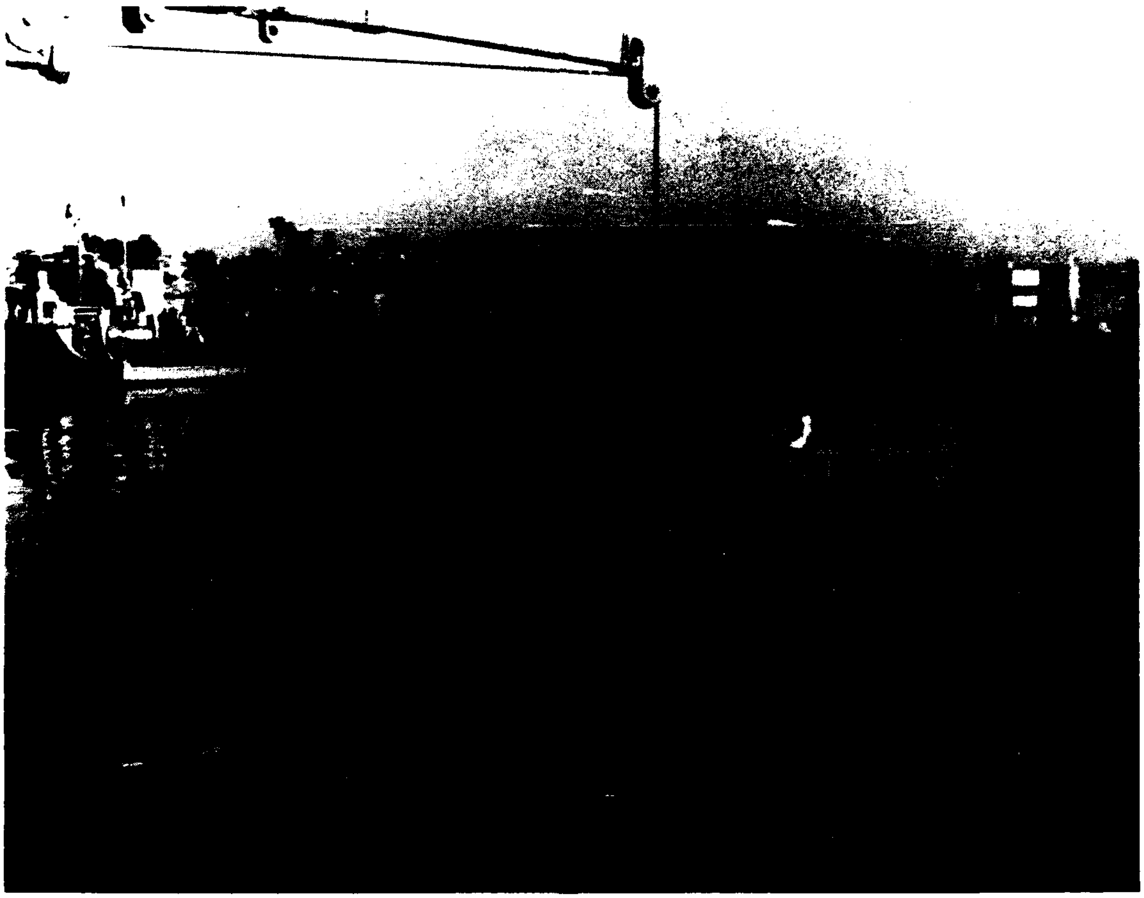
2.6 CURV IIIB

Vehicle Name:	Cable-Controlled Underwater Recovery Vehicle (CURV IIIB)
Type/Purpose:	ROV/torpedo recovery
Initial Operation:	1971
Depth:	7,000 ft
Speed:	4 knots
Weight in Air:	4,000 lb
Dimensions:	15′ × 6.5′ × 6.5′ (L × W × H)
Power Requirements:	440 VAC, 3 phase, 50 kW via tether
Propulsion:	Three 10-hp electric motors
Instrumentation:	Two TV cameras, 35 mm still camera, lights, altimeter, depthometer, active and passive sonar, manipulator
Navigation:	Magnetic compass, boat-mounted acoustic location devicc
Other:	Lost at sea



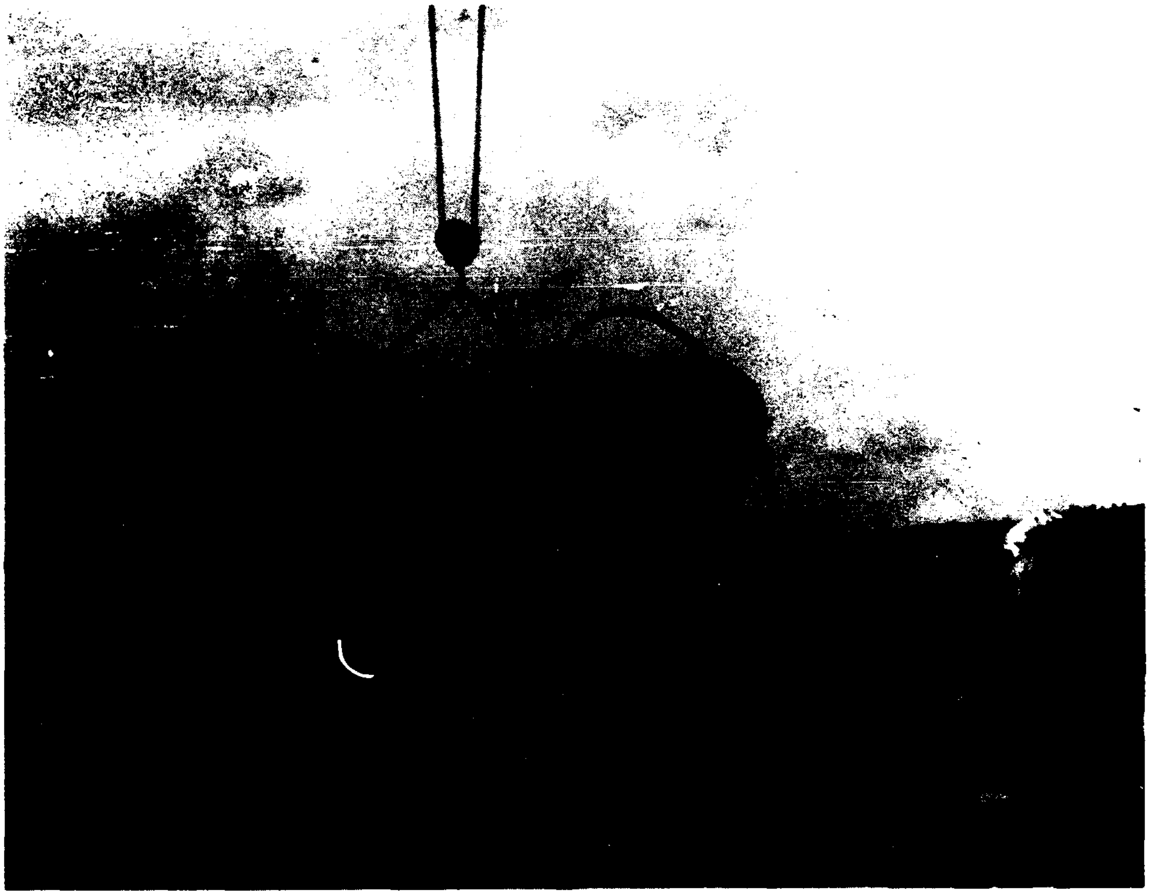
2.7 CURV IIIC

Vehicle Name:	Cable-Controlled Underwater Recovery Vehicle (CURV IIIC)
Type/Purpose:	ROV/torpedo recovery
Initial Operation:	1971
Depth:	7,000 ft
Speed:	4 knots
Weight in Air:	4,000 lb
Dimensions:	15′ × 6.5′ × 6.5′ (L × W × H)
Power Requirements:	440 VAC, 3 phase, 50 kW via tether
Propulsion:	Three 10-hp electric motors
Instrumentation:	Two TV cameras, 35 mm still camera, lights, altimeter, depthometer, active and passive sonar, manipulator
Navigation:	Magnetic compass, boat-mounted acoustic location device
Other:	Version C.1 rated for emergency operation at 10,000 ft. Instrumental in rescue of manned submersible PISCES off Cork, Ireland, in 1973.



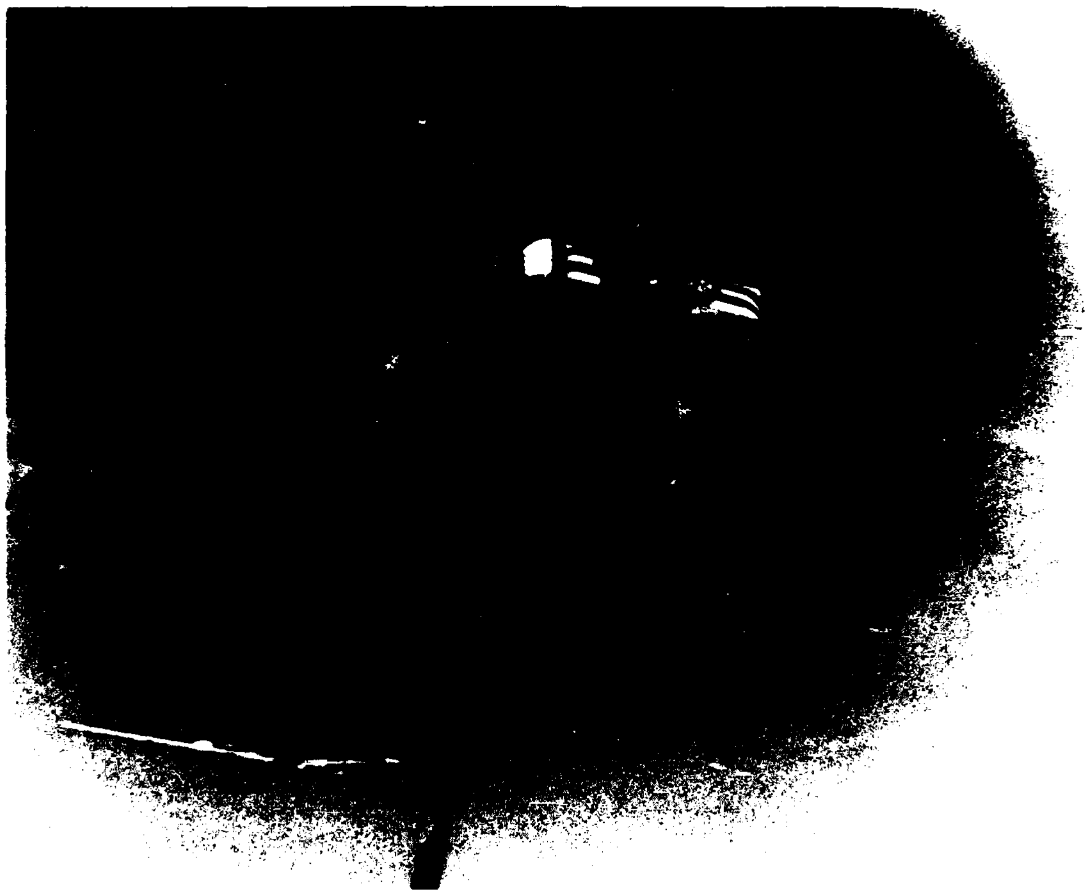
2.8 SCAT I

Vehicle Name:	Submersible Cable-Actuated Teleoperator (SCAT)
Type/ Purpose:	ROV/ research on remote presence
Initial Operation:	1973
Depth:	2,000 ft
Speed:	2 knots
Weight in Air:	400 lb
Dimensions:	6′ × 2′ × 4′ (L × W × H)
Power Requirements:	440 VAC, 3 phase, via tether
Propulsion:	Four hydraulic thrusters
Instrumentation:	Stereo TV camera system, 35 mm camera, quartz light
Navigation:	Compass
Other:	Head-coupled TV test-bed



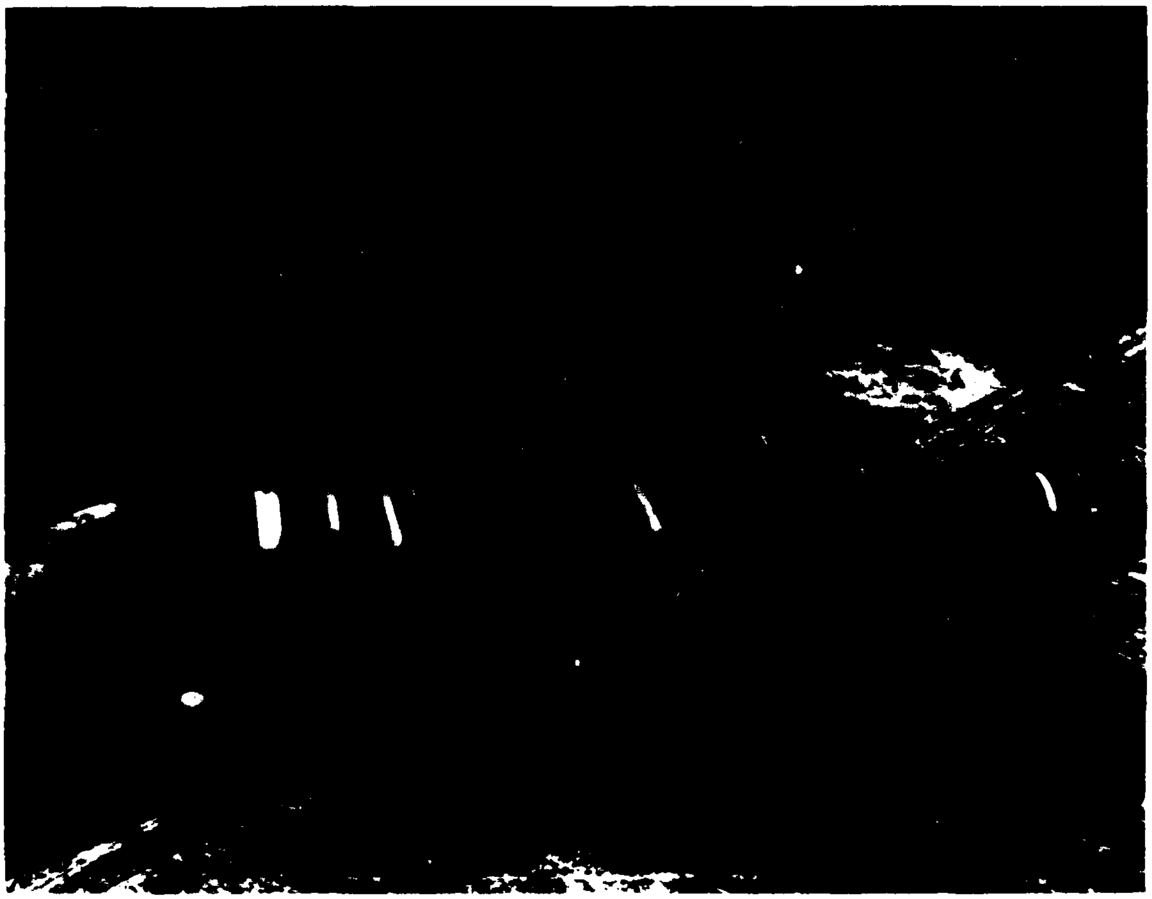
2.9 SCAT II

Vehicle Name:	Submersible Cable-Actuated Teleoperator (SCAT II)
Type/Purpose:	ROV/work and inspection
Initial Operation:	1984
Depth:	3,000 ft
Speed:	3 knots
Weight in Air:	1,000 lb
Dimensions:	44" × 72" × 49" (W × L × H)
Power Requirements:	440 VAC, 3 phase, 25 kW via tether
Propulsion:	Four hydraulic thrusters
Instrumentation:	Stereo TV camera system, quartz halogen lights, 35 mm camera and strobe, sonar
Navigation:	Gyro-stabilized magnetic compass, depth transducer
Other:	Redesigned SCAT I



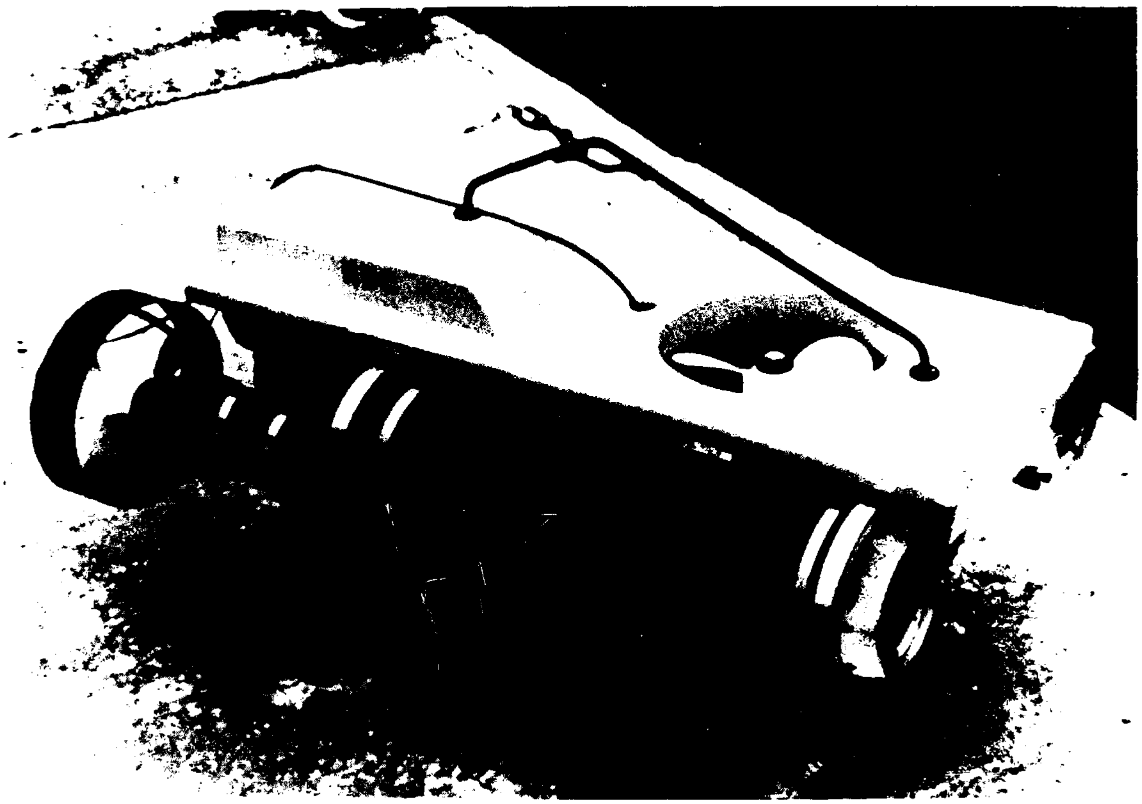
2.10 SNOOPY

Vehicle Name:	Snoopy
Type/Purpose:	ROV/remote observation, research
Initial Operation:	1972
Depth:	100 ft
Speed:	2 knots
Weight in Air:	300 lb
Dimensions:	48" × 28" × 24" (L × W × H)
Power Requirements:	115 VAC, 60 Hz, 1.2 kW, hydraulic power via tether
Propulsion:	Two hydraulic thrusters
Instrumentation:	TV camera, 8 mm cine camera, quartz iodide light, depth transducer
Navigation:	Magnetic compass
Other:	Tether made of an RG-58 cable with strength member and hydraulic lines



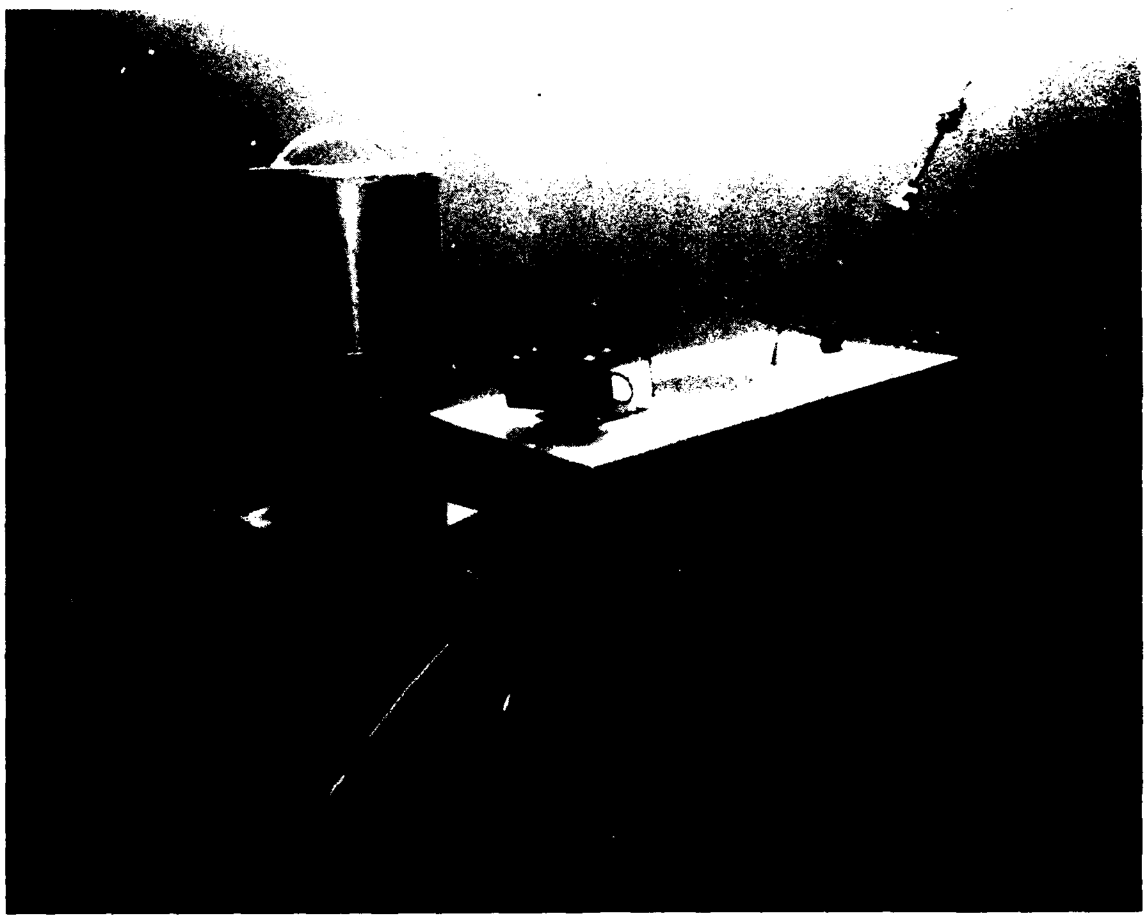
2.11 ELECTRIC SNOOPY

Vehicle Name:	Electric Snoopy
Type/Purpose:	ROV/remote observation, research
Initial Operation:	1974
Depth:	1,500 ft
Speed:	1 knot
Weight in Air:	150 lb
Dimensions:	40" × 26" × 18" (L × W × H)
Power Requirements:	115 VAC, 60 Hz, 1.2 kW via tether
Propulsion:	Three electric thrusters
Instrumentation:	TV camera, 8 mm cine camera, quartz iodide light
Navigation:	Magnetic compass, depth transducer
Other:	Tether made of two RG-58 cables with strength member



2.12 NAVFAC SNOOPY

Vehicle Name:	NAVFAC Snoopy
Type/Purpose:	ROV/limited work, remote inspection
Initial Operation:	1975
Depth:	1,500 ft
Speed:	2 knots
Weight in Air:	300 lb
Dimensions:	46" × 28" × 24" (L × W × H)
Power Requirements:	115 VAC, 60 Hz, 1.2 kW via tether
Propulsion:	Four hydraulic thrusters
Instrumentation:	TV camera, 8 mm cine camera, quartz iodide light, sonar
Navigation:	Magnetic compass, depth transducer
Other:	Tether composed of a single RG-58 cable with strength member

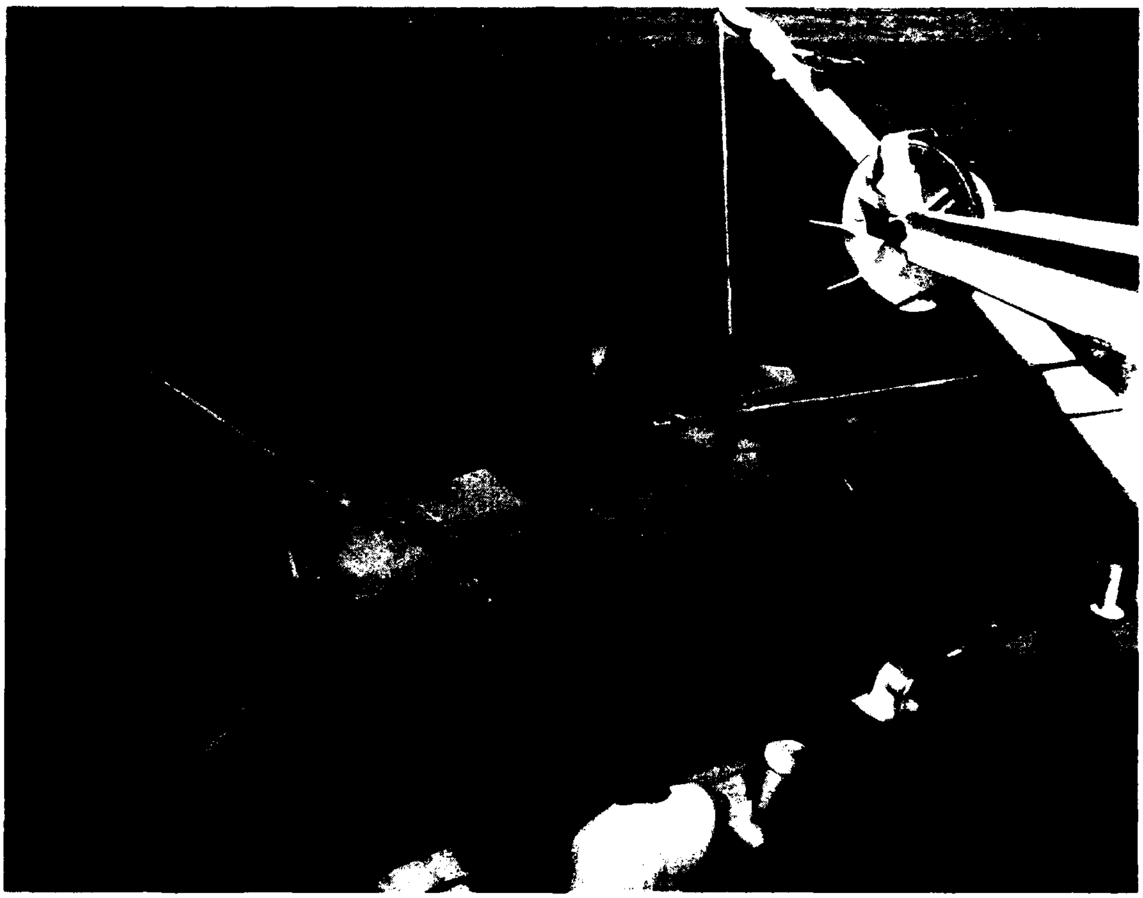


2.13 RUWS

Vehicle Name:	Remote Unmanned Work System (RUWS)
Type/Purpose:	ROV/deep general-purpose work
Initial Operation:	1975
Depth:	20,000 ft
Speed:	1.5 knots
Weight in Air:	Vehicle 7,000 lb, PCT 5,500 lb
Dimensions:	Vehicle 11′ × 4.8′ × 5′, PCT 9.6′ × 5′ × 6′ (L × W × H)
Power Requirements:	60 kW
Propulsion:	Five hydraulic thrusters
Instrumentation:	TV camera, 70 mm still camera, two manipulators, sonar, altimeter, digital magnetic compass
Navigation:	Long baseline
Other:	Two-unit system: RUWS and Primary Cable Termination (PCT) decoupling vehicle

2.14 MNV

Vehicle Name:	Mine Neutralization Vehicle (MNV)
Type/Purpose:	ROV/moored and bottom mine neutralization
Initial Operation:	1977
Depth:	NA
Speed:	6 knots
Weight in Air:	2,500 lb
Dimensions:	12.3′ × 3′ × 3′ (L × W × H)
Power Requirements:	2,400 VAC, 60 Hz 3 phase, 100 kW via tether
Propulsion:	Four hydraulic thrusters
Instrumentation:	Two CCTVs, 7 lights, 2 cable cutters, depth sensor, pitch and roll, sonar, acoustic transponder
Navigation:	Short baseline
Other:	Advanced Development Model (ADM). Prototype for production units now in Fleet.



2.15 FOCUS

Vehicle Name:	Fiber Optic Cable-Underwater Stereo (FOCUS)
Type/Purpose:	ROV/fiber-optic research
Initial Operation:	1978
Depth:	100 ft
Speed:	1.5 knots
Weight in Air:	1,200 lb
Dimensions:	7′ × 2.5′ × 2.5′ (L × W × H)
Power Requirements:	Battery, 1–2 hr endurance
Propulsion:	Three variable-speed thrusters
Instrumentation:	Stereo TV cameras, sonar
Navigation:	Compass
Other:	Voice control of vehicle added 1980

2.16 NOZZLE PLUG

Vehicle Name:	NOZZLE PLUG Solid Rocket Booster Dewatering System
Type/ Purpose:	ROV/ prototype space shuttle booster rocket recovery
Initial Operation:	1979
Depth:	200 ft
Speed:	5 knots
Weight in Air:	3,400 lb
Dimensions:	14' × 30" (H × D)
Power Requirements:	440 V, 400 Hz, 3 phase via tether
Propulsion:	Six hydraulic thrusters
Instrumentation:	TV camera, lights
Navigation:	Compass
Other:	Prototype for two production units later placed in service

2.17 ATV

Vehicle Name:	Advanced Tethered Vehicle (ATV)
Type Purpose:	ROV/deep general-purpose work
Initial Operation:	1989
Depth:	NA
Speed:	3 knots
Weight in Air:	11,000 lb
Dimensions:	20′ × 10′ × 8′ (L × W × H)
Power Requirements:	60 kW via tether
Propulsion:	Hydraulic thrusters
Instrumentation:	NA
Navigation:	Long baseline system, surface operating
Other:	Planned Fleet delivery in 1990, with IOC of 1992.

3 AUTONOMOUS UNDERWATER VEHICLES (AUV)

3.1 AUSS

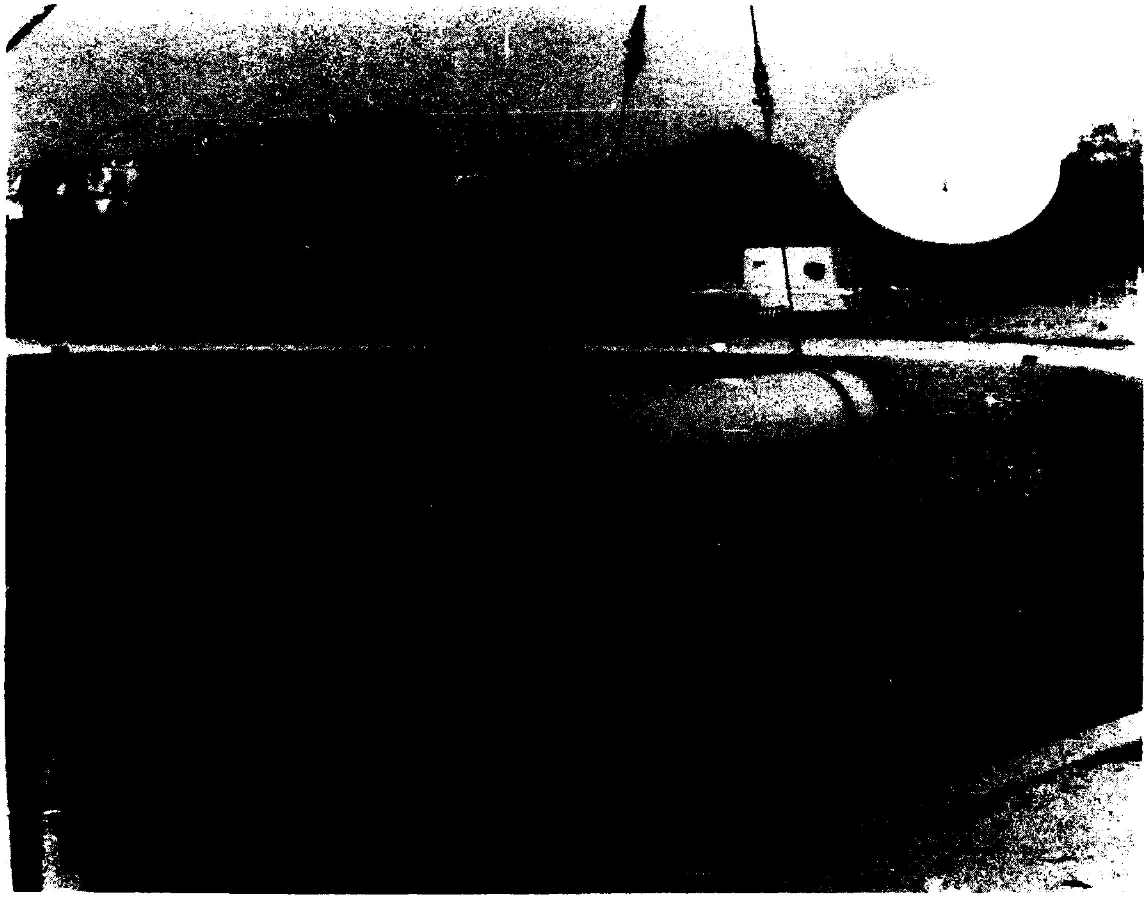
Vehicle Name:	Advanced Unmanned Search System (AUSS)
Type/Purpose:	Autonomous Undersea Vehicle (AUV)/acoustic communications link, research
Initial Operation:	1983
Depth:	NA
Speed:	NA
Weight in Air:	2,700 lb
Dimensions:	17′ × 30″ (L × D)
Power Requirements:	Ag-Zn batteries, 20 kWh
Propulsion:	Two ¾-hp electric thrusters
Instrumentation:	TV camera, 35 mm still camera, strobe, forward-looking sonar, side-scan sonar
Navigation:	Long baseline, onboard depth sensor, doppler sonar, gyrocompass for dead reckoning
Other:	Currently undergoing major upgrade for resumed test operations in 1989

3.2 FS I

Vehicle Name:	Free-Swimmer (FS or EAVE West)
Type/Purpose:	AUV/artificial intelligence and controls research test-bed
Initial Operation:	1978
Depth:	2,000 ft
Speed:	1.8 knots
Weight in Air:	410 lb
Dimensions:	9′ × 20″ × 20″ (L × W × H)
Power Requirements:	24-V lead-acid batteries
Propulsion:	Three electric thrusters
Instrumentation:	TV camera, side-scan sonar, data sensors
Navigation:	Magnetometer, compass, depthometer, altimeter
Other:	Pipeline following demonstrated in 1985

3.3 FS II

Vehicle Name:	Free-Swimmer II (FS)
Type/Purpose:	AUV/fiber-optic tether, artificial intelligence, neural network, and control research
Initial Operation:	1983
Depth:	2,000 ft
Speed:	2.0 knots
Weight in Air:	1,000 lb
Dimensions:	14' × 19" (L × D)
Power Requirements:	24-V lead-acid batteries
Propulsion:	Three electric thrusters
Instrumentation:	TV camera, still camera, lights, grabber arm, pinger/locator
Navigation:	Compass, depthometer, altimeter, acoustic homing array
Other:	Redesign of FS I using fiber-optic data link and greater internal computing capabilities.



3.4 FS-MNV

Vehicle Name:	Free-Swimmer Mine Neturalization Vehicle (FS-MNV)
Type/Purpose:	AUV/fiber-optic-controlled vehicle for advanced mine neutralization demonstration
Initial Operation:	1988
Depth:	NA
Speed:	3–5 knots
Weight in Air:	2,500 lb
Dimensions:	12.3′ × 3′ × 3′ (L × W × H)
Power Requirements:	120-V lead-acid batteries
Propulsion:	Two ¾-hp electric thrusters
Instrumentation:	TV camera, sonar, image processing
Navigation:	Compass, depthometer, altimeter
Other:	Integration of FS II and prototype MNV vehicle