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STATE-OF-THE-ART SURVEY OF HARDWARE DELIVERY AND DAMAGE INSPECT--ETC(U)
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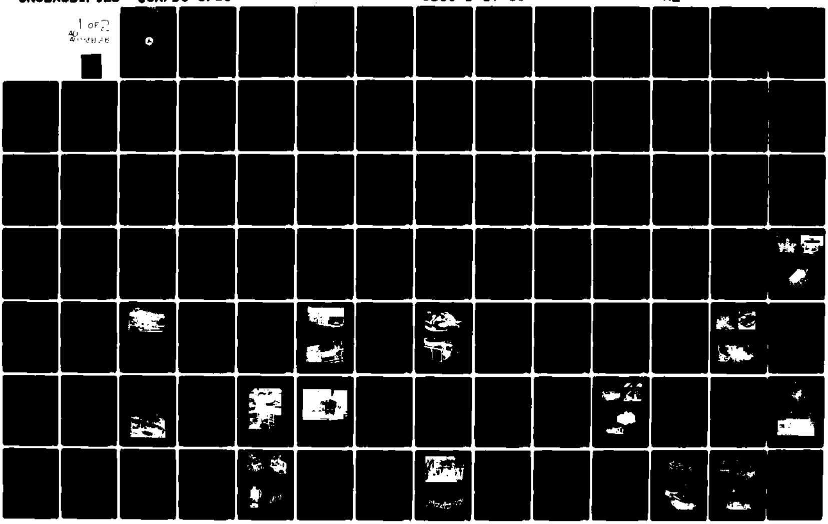

REPORT NO: CG-D-67-80

LEVEL II

STATE-OF-THE-ART SURVEY OF HARDWARE DELIVERY AND DAMAGE INSPECTION METHODS FOR COAST GUARD HAZARDOUS CHEMICAL SPILL RESPONSE

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AUGUST 1980

FINAL REPORT

PREPARED FOR

U. S. DEPARTMENT OF TRANSPORTATION
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WASHINGTON D. C. 20593

NOTICE

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16. Abstract

This report is a study of methods that might be used by the Coast Guard, in accomplishing three tasks when responding to a hazardous chemical spill originating from a tank vessel or barge in the marine environment. The specific tasks are:

1. Damage inspection of the endangered vessel;
2. Delivery of Coast Guard hazardous chemical patching and plugging devices (e.g., polystyrene foam plug, evacuated foam plug, air/water inflatable bags);
3. Delivery of a chemical sensor for venting rate measurements, sampling, and analysis for the detection, identification, and quantification of hazardous chemical pollutants.

Mission requirements and hardware design goals are established. All possible methods are reviewed and subjected to a weighted factor evaluation. The results of the evaluation indicate the most promising approach is through the application of a Remotely Operated Vehicle (ROV). Detailed information of ROVs is compiled and presented.

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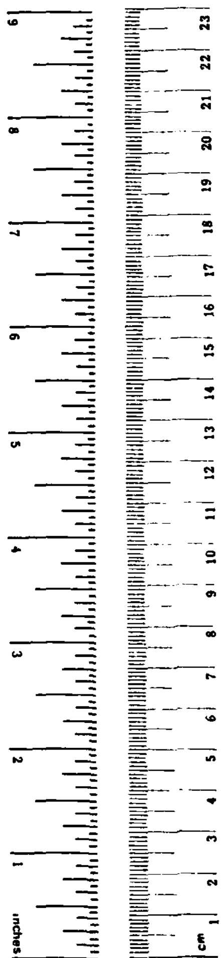
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
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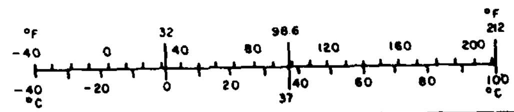
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 INTRODUCTION

This report presents the results of a state-of-the-art study of underwater technologies useful in vessel hull damage inspection, damage patching/plugging, chemical vent rate, sampling, and in-situ analysis tasks during the response activities associated with preventing and reducing the discharge of hazardous chemicals from stricken vessels. The study includes a general consideration and evaluation of the use of divers, manned submersibles and unmanned submersibles with the major emphasis on the latter category.

Technical innovations are emerging continuously in this field, spawned primarily by the tremendous development in the offshore support industries in the last five years. As a result, several reports of a similar nature have appeared recently, to keep the potential and existing users abreast of such a dynamic field. This effort does not intend to be as totally comprehensive as some, but instead, is more directed at investigating those hardware items and techniques that may be particularly suited for the very specialized mission of the Coast Guard in its hazardous chemical spill prevention responsibilities.

2.0 BACKGROUND

The marine transportation of hazardous chemicals has shown dramatic increases in both volume and variety in recent years. Associated with this increase in transport, is a corresponding rise in the potential threat to the marine environment and welfare of the general public due to the possibility of the accidental discharge of these chemicals. The magnitude of the problem is reflected by the data in Table 1. This information represents the total number and volume (in gallons) of reported spills involving hazardous chemicals.

TABLE 1
Hazardous Chemical Spills 1973-1978, from "Polluting Incidents in and Around U.S. Waters - Calendar Year 1978" (Reference (1))

	1973	1974	1975	1976	1977	1978
No.	237	220	239	299	286	268
Vol. (gal)	434,547	908,840	462,420	2,125,006	1,433,291	2,163,845

In the six-year period covered, the variation in the number of incidents is minor compared to the five-fold increase in volume in 1978 as compared with 1973. As such, the average volume per spill has markedly increased over this same period, indicating a significant benefit in terms of decreased threat to life, property and the environment, could be realized from a successful effort to stop or reduce the flow of hazardous chemicals from an endangered marine vessel.

The responsibility of responding to pollution incidents, including any hazardous chemical spills within the waters of the U.S., has been delegated to the Coast Guard. Several pieces of legislation provide the Coast Guard with sufficient statutory authority to intercede whenever there is a potential or existing pollution incident. These acts include the Federal Water Pollution Control Act of 1972 (Section 311), Ports and Waterways Safety Act of 1972, and the Magneson Act. This mission is carried out through the Coast Guard Strike Teams, and the Captain of the Port Office (COTP) responsible for the given area. Presently, however, the Coast Guard cannot respond satisfactorily to the complete range of hazardous chemical spills due to the inadequacy or non-existence of appropriate methods and hardware.

In order to more completely address the problem of marine environmental protection, and the risks associated with the bulk transport of hazardous chemicals, the Coast Guard Office of Operations promulgated a Tentative Operating Requirement calling for the "Development of Capability to Respond to NonPetroleum Spills." In response to this, an overall program entitled "Hazardous Chemical Discharge Amelioration" was developed.

The program has the ultimate objectives of:

a. Developing equipment and methods for responding to discharges of hazardous chemicals into U.S. waters.

b. Expanding and improving the Chemical Hazard Response Information System (CHRIS) hazard assessment models.

One of the six Project Areas assigned to the Coast Guard Research and Development Center (R&DC), by the Office of Marine Environment and Systems, acting as the program manager, was the "Hazardous Chemical Discharge Prevention and Reduction Project." This project is directed at the investigation and development of techniques and hardware designed to prevent the discharge of hazardous chemicals from an endangered marine vessel and to stop or reduce the spillage from a marine transport container which is already leaking.

A work unit within this project calls for the development of a hardware delivery and damage inspection system. In the following sections, the design and mission requirements are presented, followed by a state-of-the-art study and evaluation for the purposes of identifying the existing technologies that may be used in this system development.

2.1 CHRIS

As part of the effort to upgrade response readiness, the Coast Guard has recently instituted the Chemical Hazards Response Information System (CHRIS). This system is designed to provide information essential for proper decision making by responsible Coast Guard personnel during hazardous chemical emergencies. CHRIS provides a readily available data base that is composed of the following six major elements:

- A Condensed Guide to Chemical Hazards
- Hazardous Chemical Data Manual
- Hazard Assessment Handbook
- Response Methods Handbook
- Data Base For Regional Contingency Plan
- Hazard-Assessment Computer System (HACS)

The Hazard-Assessment Computer System is the computerized counterpart of the Hazardous Chemical Data Manual and Hazard Assessment Handbook. Using some field input describing the spill situation, the computer model gives a very detailed hazard evaluation. Graphic output displays may be provided which show the relationships among spill concentration, thermal radiation, location, and time. HACS may also be used for advanced planning in spill response procedures by simulating a chemical spill in a given area.

Currently, however, the model calculates a venting rate by assuming leakage from a hole above the waterline in a tank of uniform cross section. Reference (2) indicates, for the vessels surveyed, that as much as 50 percent of the damaged areas lie below the waterline. This type of damage could result in a significantly different venting rate and total volume released, than that calculated by HACS. As the entire hazard assessment output by HACS is based on the venting rate figure, it is of primary importance that this figure be as accurate as possible.

2.2 Hardware Items for Hazardous Chemical Response

Several pieces of hardware, designed to extend the Coast Guard hazardous chemical pollution response capabilities, are undergoing concurrent development. Protective clothing, with integral breathing apparatus, and environmental monitoring devices, for personnel operating in the vicinity of hazardous chemicals, is undergoing final development at Coast Guard Headquarters under the Project entitled, "Personnel Protection." Pre-prototype versions of the protective suits have been distributed to the Strike Teams, providing some interim capability for safer operations in hazardous environments.

Additionally, a Vapor Reduction Device has been developed at the R&DC under the Hazardous Chemical Spill Prevention and Reduction Project. This device effectively reduces toxic vapor concentrations around a standard deck opening during pumping operations conducted while a vessel is undergoing emergency lightering of hazardous chemicals.

To date, however, such provisions have been limited to topside personnel, while diver operations are naturally suspended when hazardous chemical concentrations reach unsafe levels in the water.

Three basic types of patch and plugging devices have also been developed at the R&D Center. The polystyrene foam plug, evacuated foam plug and the air/water inflatable bag plugging system, represent significant developments in hardware items for the reduction of hazardous chemical discharge due to vessel hull damage.

Present efforts include the development of a near-term underwater damage inspection capability. This has resulted in the procurement of an underwater TV camera system by the R&DC. This system is a high resolution, black and white video unit which can be deployed in either a diver hand-held, or remotely operated, pan-and-tilt-mounted mode. The system is certified explosion-proof for safe operations in the vicinity of flammable vapors. A video recorder is included for damage evaluation and documentation purposes. An underwater video unit will be a key component in any system designed for the remote inspection of marine vessel hull damage, and the procurement of this item provides hardware for operational tests and evaluation as well as the opportunity for Coast Guard R&D personnel to establish expertise in this area.

Chemical sensor packages are being developed in support of the Detection, Identification, and Quantification Project. A preprototype version of a towable fluorometer has been built. This device is capable of real-time concentration measurements of a number of organic compounds that fluoresce in water. Work has also been done on a prototype X-ray analyzer. This device is a field-deployable unit that measures the concentrations of elements falling between calcium and uranium on the periodic table.

The end users of the hardware output items mentioned will be Coast Guard pollution response personnel; particularly the Strike Teams and Captains of the Port (COTP's). Once these items reach the field, the response teams will have the ability to work safely in the vicinity of hazardous chemicals while wearing the protective clothing, and increase safety of emergency offloading procedures through use of the vapor reduction device. The plugging devices will provide the capability for hazardous chemical discharge reduction from a variety of hull damage configurations.

The development of an advanced hardware delivery and damage inspection system will provide major contributions toward achieving the overall program and project objectives, and facilitate the use of task-related hardware by satisfying the following mission objectives:

1. Provide inspection, damage assessment, and documentation capabilities of an endangered tankship or barge that is carrying hazardous chemicals in bulk.

2. Provide a platform capable of delivering the hazardous chemical patch/plugging devices.

3. Provide a platform capable of delivering the chemical sensor and sampling hardware for the determination of the hazardous chemical outflow (venting) rate from a damaged vessel for use with HACS models and for possible use in the detection, identification, and quantification of hazardous chemicals at or in the vicinity of an incident.

In any marine incident with a potential for causing a polluting spill, optimum response for spill prevention and reduction is predicated on fast and accurate damage assessment information. This information provides critical input to HACS when formulating the hazard assessment and response tactics. In addition to real-time video information, the data may be preserved in the form of still photographs and videotape recordings. This may prove valuable in any permanent documentaion or legal proceedings concerning the incident. Presently, this capability is nonexistent within the Coast Guard in instances where hazardous chemical concentrations in the water preclude the use of divers.

Currently, the use of underwater patches and plugs is likewise limited to instances where divers can safely operate around an endangered vessel. A platform capable of delivering these devices without further endangering operating personnel would significantly increase response effectiveness. In hazardous chemical spill situations, the inspection/delivery platform provides an essential link between response personnel operating safely on the surface and the array of underwater tasks necessary for successful spill prevention and reduction measures.

Sampling and analysis capabilities are critical to determining the venting rate of hazardous chemicals into the marine environment. COMDTNOTE 16450 of 16 May 1968 states "Special efforts should be made to determine the amount of substance (by weight) which reached the water since the "sheen test" is not available for hazardous substances discharges...Proper and thorough investigation will be essential in hazardous substance discharges because of the need to determine the amount discharged." A real-time sampling and analysis capability would allow determination of the actual venting rate and provide this data for input to the hazard assessment model, rather than relying on calculations based on assumed damage location and tank configurations. Accordingly, improved hazard assessment and spill response actions could result in an overall decrease in hazard to life, property and the environment.

3.0 APPROACH

In order to reasonably assess what particular technologies might be employed in developing a hazardous chemical container damage assessment and hardware delivery system, the mission requirements and design goals should be well defined. In view of this, and the very specialized task capabilities required of this system, the following requirements have been established.

3.1 Mission Requirements.

1. Damage Assessment. The system should provide the capability to locate and assess the extent of damage sustained by a hazardous chemical tank vessel or barge with minimum hazard to operating personnel. "Locate" implies sufficient navigational capability to determine where the damaged areas of a tank vessel are, with respect to some reference point. "Assess" indicates the ability to acquire quantitative information about the damage; that is, the number of damaged areas, the physical characteristics (indentation, hole, crack) and dimensions.

2. Venting Rate/Sampling and Analysis. The damage assessment system should also provide sufficient information to determine if, and at what rate, a hazardous chemical is leaking from a damaged vessel. This may be accomplished either directly, through the use of sensors deployed in, or near, the leak source, or indirectly by making flow calculations based on the damage assessment information. Consideration must be given to effects on the system due to a secondary requirement of incorporating a device which could be used for sampling and/or in-situ analysis of pollutants in support of chemical detection, identification, and quantification efforts.

3. Plug Delivery. Once the damage to a stricken vessel has been assessed, the capability to deliver any of the three patching and plugging devices is required. Delivery involves returning to the damaged location, maneuvering the patch/plug into position, and activating the device to form an effective barrier that will stop or reduce the outflow of hazardous chemicals from the tank.

3.2 Design Goals.

In order to assure that the damage assessment and delivery system can be used safely and effectively in a majority of hazardous chemical incidents, the following design goals are cited:

Primary

1. Environmental - The system should be effective in the damage assessment and delivery tasks associated with a stricken vessel carrying hazardous chemicals, in fresh or salt water, under the following environmental conditions:

Air Temperature	- 32°F to 100°F
Wind Speed	- up to 30 knots
Water Temperature	- greater than 32°F
Water Depth	- up to 50 feet
Current Speed	- up to 1.5 knots

Wave height	- up to 6 feet
In-water Visibility	- down to 3 feet

2. Versatility - The system must be useful over a wide range of situations. In some cases, access to the damaged area may be restricted, especially on a vessel hard aground and in certain collision incidents. However, it is estimated that a damage assessment system could be used in the majority of cases where damage extends below the waterline on the end rakes and sides of a vessel, as well as in some cases involving bottom damage. Reference (3) indicates that side damage occurs nearly twice as often as bottom damage in tank barges. The specific requirement placed on the system is that it be capable of dealing with holes up to 5 square feet in area and cracks up to 3 feet long. The Tank Barge Study indicates that this would include approximately 55% of the holes and 68% of the cracks in the damaged vessels surveyed. The damage assessment capability of any system designed may well exceed this criteria; however, it is compatible with the patching and plugging devices that have been developed.

3. Safety - The device must be designed such that it may increase the effectiveness of discharge prevention and reduction efforts without increasing the hazards imposed on response personnel. As such, any components containing possible ignition sources should meet the explosion proof and safety standards of the National Fire Protection Association (NFPA) Standard No. 496 for Class 1 Division 1 locations where hazardous concentrations of flammable gases or vapors may exist. Reference (4) contains details on these safety standards.

Secondary

1. Chemical Resistance - The equipment should be constructed of materials that are compatible with as many of the CHRIS chemicals as is technologically feasible. The chemical compatibility should be optimized in order to maximize the number of chemical cargos in which the system may be used, as well as extend the lifetime of all reuseable components.

2. Deliverability - The complete system should be modularized for delivery by Coast Guard vessel, aircraft or helicopter, for a minimum response time. Size and weight of each module should allow for rapid delivery from the storage location to the staging area and then to the incident scene. Where feasible, a single module should not exceed the carrying capability of two persons.

3. Operability - The system should have a minimum set up and deployment time. It should be minimally dependent upon outside support, and compatible with developing and existing Strike Team spill prevention hardware items that are used in the mission requirement tasks. The system should be able to function at least 8 hours without additional outside support.

3.3 Survey Approach.

The approach used in this survey is initially to conduct an extensive literature review in order to compile the background information in all areas of consideration. Based on this, and existing knowledge of the mission requirements and possible techniques that might be employed, a Deployment Method Evaluation screening is used to refine the areas deserving further investigation. In addition to the R&DC evaluation, the expertise of Navy personnel is incorporated in order to give added perspective to the evaluation. The results of the various evaluation forms are compiled and averaged for the initial Deployment Methods Screening.

Following the initial screening, further effort is devoted to specific systems in the categories showing the greatest promise for success. More detailed information obtained through telephone interviews and personal contacts, as well as manufacturer's published information and technical reports, is presented in a standardized format. Evaluation of the specific systems is performed based on satisfying two levels of mission capabilities: inspection and inspection/delivery. This evaluation process is illustrated in Figure 3.1

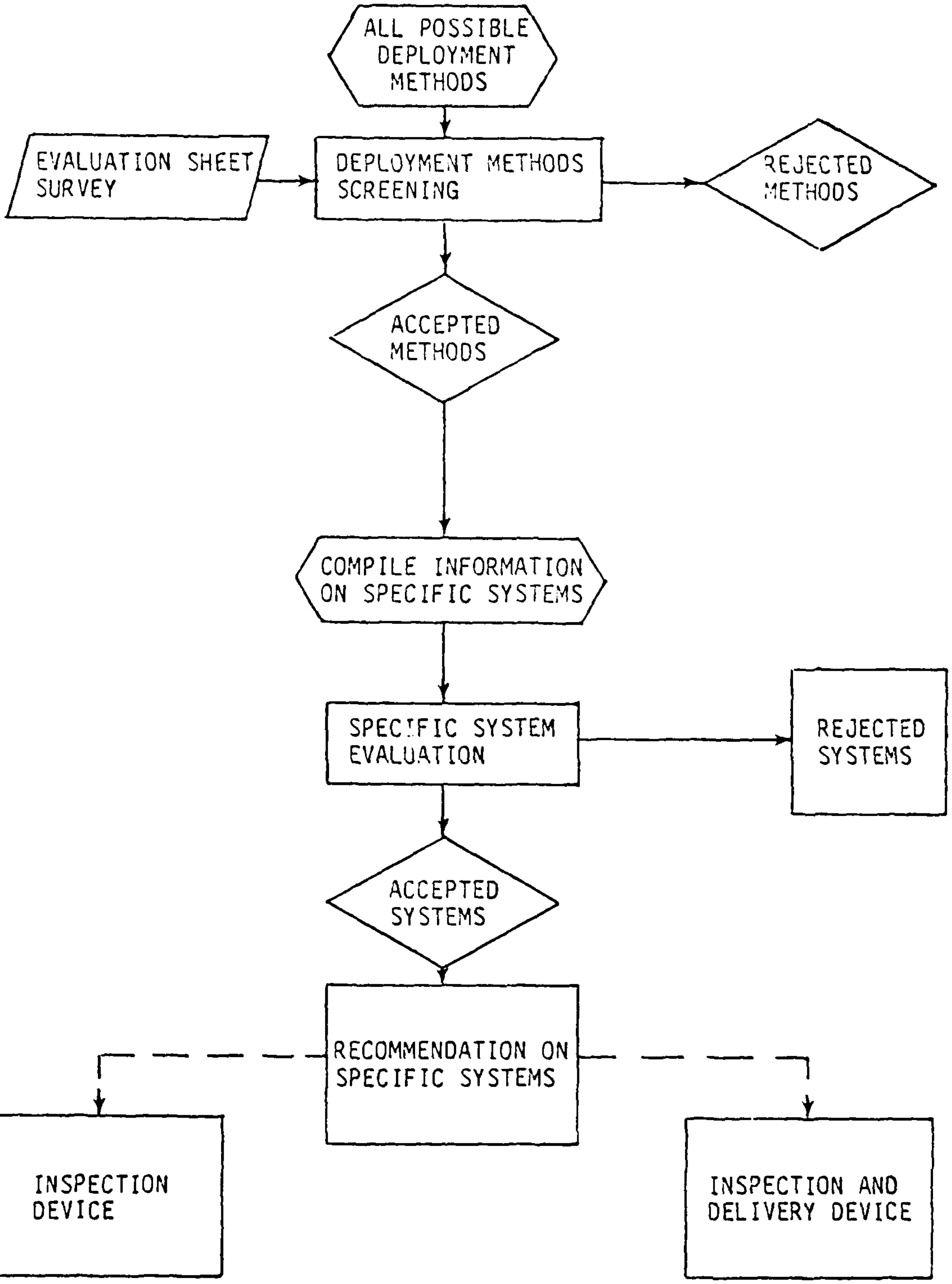


Figure 3.1 Evaluation Flow Chart

4.0 DEPLOYMENT METHODS

Presently, the Coast Guard has a very limited capability to conduct underwater tasks. This ability is reduced drastically in hazardous chemical spill response activities. Strike Team divers using band masks and, in some cases, standard SCUBA, have performed extremely well in oily water; however, these operations are marginal due to the hazards to personnel and equipment. In the majority of hazardous chemical cases, safety precautions unquestionably preclude any underwater operations by personnel using equipment presently in the Coast Guard response team inventory. As such, the initial step is to review and evaluate the basic techniques presently used for a variety of underwater work tasks outside the Coast Guard. A key item in the evaluation criteria will be applicability/adaptability to the specialized mission in the hazardous chemical environment. It should be noted that the Navy Coastal Systems Center in Panama City, Florida, is in the process of developing an improved dry suit for use by divers in polluted waters. The R&DC has provided NCSC with a list of chemicals to which Coast Guard divers might commonly expose a diving suit. Technical evaluation is scheduled for July 1980. Upon successful completion of this effort, underwater operations by divers in some hazardous chemical spill situations may be possible. Further work would be required to make this a safe practice when using standard SCUBA, but when used in conjunction with techniques similar to those established by commercial diving companies for tasks in biologically polluted waters and nuclear reactor tanks, this suit could significantly extend diver capabilities.

The major categorical division in deployment methods is between manned and unmanned, or remotely operated systems. Approaches within each category are considered and a brief review of each follows.

4.1 Manned Systems

4.1.1 Diver

There are basically three approaches in ambient pressure diving:

1. Self-contained underwater breathing apparatus (SCUBA).
2. Surface-supplied air or mixed gas.
3. Subsurface-supplied gas using a diving bell.

The diver's ability in dexterous manipulation, visual perception and on-scene intelligence is basically that of a human being on land. However, each capacity may be reduced to a greater or lesser extent, depending on the particular operational conditions. Divers are frequently required to operate in a "zero-visibility" environment which places great reliance on human dexterity, tactile sensitivity, and diver experience. The combination of dexterous manipulation and on-scene intelligence is often a key faculty in accomplishing an underwater task. The encumbrances of life support equipment, including diving suits, the rigors of breathing compressed gas, and the narcotic effect of some gases under pressure, all act to degrade human performance in these areas. Due to general safety requirements, few deep task requirements, and the lack of portable recompression chambers, all Coast Guard diving is restricted to less than 170 feet and within the depth/time constraints of no-decompression diving as set out by the U.S. Navy Diving Manual. See Reference (5).

4.1.1.1 Self-Contained Underwater Breathing Apparatus

A SCUBA diver carries his complete life-support package with him, including breathing gas. This mode offers maximum mobility and freedom from a surface umbilical while being limited by the duration of self-contained air supply, the narcotic effects of nitrogen at depth, and difficulties in establishing effective communication diver to diver, or diver to surface. The Coast Guard presently maintains a capability in this area, primarily within the Atlantic Strike Team Unit. Coast Guard SCUBA diving operations are conducted with a minimum of four personnel: two divers, a standby diver and a diving officer. Equipment is maintained for standard wet suit or dry suit (Unisuit) modes.

4.1.1.2 Surface-Supplied

Surface-supplied diving is frequently used in commercial and military diving operations. Breathing gas is supplied from the surface to the diver via the diver's umbilical hose. The diver may wear either a standard hard hat or lightweight mask with a face seal, and a wet suit, dry suit, or hot water suit. A hardwire communications link, in addition to a lifeline, and pneumofathometer are usually married to the breathing gas umbilical. The breathing gas may be air, or for deeper dives, mixed gas. The primary advantages of surface supplied diving are increased gas supply, and direct communications with the surface. This is at the expense of decreased mobility and greater personnel and logistic support at the surface. The Coast Guard Atlantic Strike Team currently has three lightweight band masks (KMB-9) with 200-foot umbilicals for use with this type of diving. Coast Guard procedures call for six personnel during surface-supplied dives: one diver in the water, one standby diver, two surface tenders, one surface communications operator and a diving officer.

4.1.1.3 Subsurface-Supplied

This method involves dives on an umbilical with the gas supply contained in a diving bell deployed below the surface. A diving bell is usually launched on a tether from a dive support vessel; the bell is pressurized and once the working depth is reached, divers egress to perform their task. After the mission is completed, the divers return to the bell which is then winched to the surface. Longer and deeper dives require decompression which may be conducted in the bell or, more frequently, in a deck decompression chamber. A special breathing gas mixture is often used in this mode.

For underwater jobs at a deep depth which require extensive bottom work time, closed bell diving may also be conducted in a saturation mode. In this case, divers are usually pressurized in a deck chamber to a saturation depth equal to the working depth. The divers are then transferred to a submersible decompression chamber and lowered to the work site. Dives are conducted on a tether from the submersible chamber which carries the breathing gas supply. Diver's dress usually consists of a hot water suit and commercial diving hat. Once the work task is completed, the divers return to the submersible chamber which is maintained at working depth pressure while it is raised to the surface. The divers are transferred to the deck chamber where they may either remain under pressure in anticipation of another dive, or undergo decompression.

Subsurface supplied techniques are reserved primarily for deep and/or extended duration dives. This technique allows the diver to operate on a much shorter umbilical, resulting in minimum drag in current conditions which would otherwise severely hamper or prevent diving in a surface supplied mode. Also, the diver is offered the comfort and safety of the submersible chamber and deck chamber for all but the actual excursion time during which the work tasks are performed. However, the systems required for this mode are complicated and very costly in terms of personnel and topside logistic support and they necessitate a high degree of expertise to operate safely. This method is not a likely candidate for the damage assessment and hardware delivery tasks, but is included here to provide perspective on the complete range of diving techniques.

4.1.2 Manned Submersibles

Included in this category are a variety of manned, noncombatant craft, having the capability of supporting the occupants in a dry, one-atmosphere environment. The majority of these vessels are untethered, free-swimming vehicles. However, the tethered, one-atmosphere observation bell fitted with thrusters for limited mobility, and equipped with manipulators, has recently established itself as a useful underwater vehicle type. The other main category of tethered, manned submersible vessels is the advanced, single-man, Atmospheric Diving Suit (ADS).

4.1.2.1 Manned Untethered Submersibles

Early developments in manned, untethered systems were primarily the result of special applications and research needs. In the last decade, however, the commercial market has supported tremendous growth in this area, resulting in a world-wide commercial fleet of approximately 100 vessels. This number is difficult to determine precisely due to the dynamic nature of the field. It is even more difficult to define the typical capabilities of a vessel in this category as the designs vary widely from builder to builder, and even from vessel to vessel, within the same class. However, a survey conducted by Busby Associates (Reference (6)) described the industrial fleet, as of early 1978, with the following parameters (numbers represent a fleet average):

Size: Length = 20.3'; beam = 7.5'; height = 8.9'
Weight: From 2 to 26 tons
Maximum operating depth: 1875'
Cruise speed/endurance: 1 kt for 7.9 hrs
Power source: Lead-acid batteries
Crew: 2 to 6
Dive duration: 6 to 8 hours
Payload: 1050 pounds
Manipulator: Approximately 80% have 1; 40% of these have 2
Launch/retrieval: up to sea state 4

When considering the applicability and effectiveness of the manned submersibles, it must be remembered that the submersible vehicle itself is one item in a total system which also includes a support vessel, communication and navigation equipment, and handling system. This may be true with alternate systems as well; however, the implications are greater when various components must be man-rated. Some of the requirements and design considerations that must be made to ensure the safety and effectiveness of the human occupants are as follows:

Environment:

Breathing Gas - The one-atmosphere environment must be maintained with sufficient oxygen replenishment and carbon dioxide removal for dive duration and emergency situations. If the vehicle has diver lock-out capabilties, diver's breathing mixture is also carried.

Temperature and Humidity - Submersible vehicles encounter wide extremes in temperature in a medium with a high heat capacity. Temperature control efforts often produce high humidity and condensation on the vessel walls. Both factors must be controlled for the safety and effectiveness of the occupants and equipment.

Rations - Sufficient food and water must be carried for dive duration and emergency situations. Power restrictions limit those foods requiring extensive preparation.

Waste Management - Means must be provided to treat and store metabolic wastes for the dive duration.

Comfort - The internal layout must be such that long periods submerged do not result in pilot or observer fatigue.

Emergency Situations:

Entanglement - The exterior design of the vessel should allow a limited number of protrusions beyond a smooth fairing surface to minimize the possibility of fouling on foreign objects. Due to the limited life support resources, detailed contingency plans must be made in advance in case of vessel entanglement.

Power Loss - The vehicle should have a mechanical means of surfacing (blowing water ballast, jettisoning emergency ballast, etc.) in the event of complete power loss.

Fire and Noxious Gases - Materials used within the pressure hull must be selected to minimize potential outgasing and fire hazards. Fire extinguishers and emergency breathing apparatus must be provided for such emergencies.

Tracking Loss - Due to the possibility of loss of acoustic contact, the submersible must be provided with emergency methods of signaling once it reaches the surface, in the event that the standard tracking contact or communications link cannot be reestablished with the support ship.

Support Requirements:

Transportation - The size and weight of a manned submersible is significant and generally determines the system mobility. In some cases transportation can only be effected after dismantling major components, which in turn affects the system response time.

Support Platform - In nearly all cases, a submersible vehicle requires a support platform. In most instances, submersibles are deployed from a support vessel. The vessel must have adequate facilities to maintain the vehicle, house the support and scientific crew, and perform work tasks in conjunction with the submersible. The vessel must also have sufficient navigation, maneuvering, and tracking capabilities to support submersible operations effectively.

Launch and Retrieval Systems - Usually the submersible is transported to the work site via a support vessel and launched once it is on scene. In this case, a crane or articulating A-Frame is generally used. Other means of deployment/retrieval include a submersible platform which may be deballasted to launch or receive the submersible, or a mechanical elevator attached to the surface vessel. Alternately, a mother sub may provide the launch platform, in which case the entire operation is conducted in a submerged mode, eliminating the handling problems encountered at the air/sea interface. In any case, the launch/retrieval system is a critical component of the submersible system and, as such, must be fully compatible with the gear it is serving and be certified for handling manned systems.

Capabilities:

The primary advantage of manned submersibles is the ability to deliver a human being to the underwater work site and support him in a comfortable, one-atmosphere environment. To be effective, the vehicle must be designed to optimize the human performance and integrate it within the complete system. Due to recent advances in unmanned vehicle technology, the only distinguishing feature is the ability for man to see directly what is going on about him. All other functions and sensing capabilities are ultimately performed in a remote mode. As such, the vessel should be designed for maximum visibility. Older submersibles usually have a number of relatively small viewports through which an observer can operate, severely limiting the field of view. More recently, designers have employed acrylic and glass in the construction of very large viewports and transparent bow sections for improved visibility.

The majority of submersibles have at least one manipulator. These can range in complexity from a simple, two-function grabber arm to a seven or eight-function manipulator. Rate proportional and force feedback models are presently used on some vehicles. Power is usually supplied by electro-hydraulics. Lifting capability at full extension ranges from eight pounds to as much as 2,500 pounds, although this depends largely on the vehicle size as well as the manipulator capacity. The manipulator provides a certain amount of dexterity and nearly all vehicles can be fitted with a variety of work tools including drills, wrenches, grinders, brushes, etc. Grabbers are often used to hold a vehicle in a fixed position relative to the work area on a structure, especially in mid-water tasks. In some cases, this is also done magnetically.

Most working submersibles also provide external attachment points for various instruments, in order to increase mission adaptability. Many vessels also have a diver lock-out capability which allows a diver to perform tasks while an observer or more technically qualified person monitors his activities on site and remains in a dry, one-atmosphere environment.

Mission endurance and effectiveness can be restricted by the following characteristics of manned, untethered systems: a limited power supply; finite resources for maintaining the life support systems; human occupants, placing greater emphasis on safety considerations; and a relatively large vehicle that may suffer restricted access to confined areas.

4.1.2.2 Manned Tethered Submersibles

There are two main vehicle types within this category that are presently in use: the tethered observation bell and the atmospheric diving suit (ADS).

Tethered Observation Bell

These vessels are similar to the closed vessel used in deploying subsurface supplied divers, with a few notable exceptions. The vessel is used for observation and some work tasks with the occupants remaining in a one-atmosphere environment. Thrusters (usually 2 to 4) provide the vessel with a limited degree of mobility. A manipulator provides the dexterity for accomplishing work tasks and a grabber arm is often fit for maintaining position on a structure. Although on a tether, these vessels generally carry the breathing gas supply on board. The tether is reserved for lifting/positioning by the support ship and for hard wire communications to the surface. This type vehicle usually consists of a single pressure sphere in a framework, with functional units and instrumentation attached externally. Except for the limited mobility and lack of diver lock-out capabilities while maintaining a pilot/observer at one atomosphere, this system has mission capabilities similar to a manned untethered submersible. A simpler design, smaller size and lighter weight are to its advantage when compared with its free swimming counterpart.

Atmospheric Diving Suit

The ADS is the simplest and smallest of the manned submersibles and represents a hybrid of the diver and manned submersible categories. The metal alloy suit allows the wearer to operate at depth, much as a diver, while remaining at atmospheric pressure. Manipulation is provided by operating the suit "sleeves" which have articulated joints to allow full arm movement and dexterous fingers or a claw as the manipulating device. There is adequate room inside the suit to allow the operator to use a camera, recorder or other electronic device. Maneuverability and locomotion is supplied by the diver's legs or, in some cases, thruster units. The suits with propulsion units are not limited to bottom tasks but, by virtue of their hovering capability, can perform some mid-water tasks.

An ADS has minimal support requirements. The life support and power systems are self-contained. The suit and frame occupy only 15 to 20 $feet^2$ of deck space. Lifting weight of a suited diver is somewhat less than 1,500 pounds. A complete system including suit, small winch/handling system and spare parts kit is transportable by helicopter.

4.1.3 The Cost of Manned Submersible Systems

Including man as an essential component in an underwater observation or work system requires extensive justification because the cost is high for maintaining human occupants safely in the hydrospace. An adequate life support system must be maintained which substantially increases the overall weight and complexity. Most systems require a self-contained power source which also increases weight and limits mission endurance. The pressure hull required to maintain a safe environment for the occupants is often the largest, heaviest and most costly part of a manned submersible. Once constructed, the entire system must undergo man-rating certification which also demands a healthy price. The launch/retrieval operations are necessarily limited by sea state due to the possibility of injury to the submersible occupants during rough handling. The overall handling problems are increased due to the greater size and weight of manned systems, as well as the requirement for a special fail-safe handling system. All these factors act to decrease the system cost-effectiveness based on costs incurred that are not directly related to accomplishing the mission task. This is true enough in the submersible systems presently available and it is inevitable that the costs, in terms of personnel risk and dollars, would increase significantly for a manned system especially adapted for operation in a hazardous chemical environment. Additionally, the maintenance costs for a manned system subjected to such a hostile environment would be substantially greater when compared with a remotely operated system.

4.2 Unmanned Systems

The vehicles within this category are generally of four types: tethered vehicles of the free swimming, bottom crawling or towed types, and the more advanced, untethered, free swimming vehicles. The systems are unmanned to the extent that there is no provision for human occupants in the submerged vessel. However, in all cases, an operator is required at some point for the system to function usefully. Various names and acronyms have been attached to vehicles of this sort, such as cable-controlled unmanned vehicle, remotely manned undersea vehicle, remotely controlled vehicle (RCV), and remotely operated vehicle (ROV). Hydro Products of San Diego, CA, one of the first companies to make a significant venture in the commercial marketing of such vehicles, has registered RCV as their trademark. For the purposes of this study, the terms remotely operated vehicle and ROV shall be preferred.

The last six years have seen a sharp increase in the number and sophistication of ROVs. In 1974 there were less than 20 such vehicles. This number has increased nearly ten-fold as of this writing, and is growing steadily. In addition, there are approximately 125 ROVs, designated PAP-104, which are constructed in France and employed by various navies as mine neutralization vehicles. Otherwise, the offshore oil industry has been the primary consumer in this expanding market, followed by the military, and finally, the scientific community.

The relative infancy and dynamic growth of the ROV industry is such that the performance capabilities and designs vary as widely from vehicle to vehicle as manned submersibles. Consequently, each category shall be discussed separately.

4.2.1 Tethered Remotely Operated Vehicles (ROVs)

Tethered ROVs are of the free-swimming, bottom crawling or towed type. The general similarities that exist among these types are: a reliance on an umbilical tether to supply surface generated power, a control function pathway, and a strength member for surface handling; the use of closed circuit TV (CCTV) for real-time viewing; and the necessity for a surface platform for control, support facilities, and maintenance. Although the basic configuration varies significantly from type to type, similar components are often used to complete a system of each type.

4.2.1.1 Free-Swimming ROVs

A tethered, free-swimming vehicle system consists of a submersible, self-propelled vehicle, an umbilical cable, and a surface control console. In some cases, an underwater clump or launcher is included for the purposes of isolating the vehicle from the main cable dynamics resulting from surface vessel motion, and to minimize the effects of cable drag on the vehicle's maneuverability. The support equipment consists of a launch and retrieval system, cable winch, and support area for the operators and control console. If shipboard power is unsuitable or unreliable, a power supply unit is also required.

Most ROVs of this type have an open, metal framework which supports and protects the system components. Buoyancy is usually adjusted to be a few pounds positive, often by the use of syntactic foam blocks mounted on the top of the vehicle. Some vehicles are constructed with a smooth spherical hull of foam or fiberglass which encloses most of the various components. The smooth, closed hull generally has less drag for a greater speed-to-power ratio and more maneuverability, while the open frame is more suitable for hovering and offers greater flexibility in mounting components based on varying task requirements.

The "average" vehicle in this class is approximately 90"x53"x47" (LxWxH), weighs about 1,000 pounds, and has a depth rating of about 3,000 feet. However, there is a wide range in specific values from vehicle to vehicle. The average vehicle speed close to the surface is between 1.5 and 2.0 knots. Cable drag may cause a significant reduction in speed and maneuverability at greater depths with systems not employing a clump or launcher. Most vehicles can be launched and retrieved in conditions up to Sea State 4, but this is dependent on the sophistication of the handling equipment available. Support/operating crews average three to four persons.

Nearly all the tethered, free-swimming vehicles are propelled by thrusters which provide three-dimensional maneuvering capabilities. Two longitudinal propulsers generally provide forward and reverse thrust and yaw motion, and one vertical thruster allows heave control. A fourth unit may be mounted laterally to control translational motion.

In all cases, CCTV is used to provide real-time video information for operations control and observation. Some systems include a second camera, devoted exclusively to the observer, while the operator maintains control through the primary camera. Stereo TV systems are available and would seem to offer definite advantages during manipulator operation; however, their use in ROVs is currently very limited. Some vehicles carry low light level cameras with silicone intensified target (SIT) tubes to deal with the special problems inherent in underwater video. Most cameras used on ROVs are black and white but, as the resolution of color systems is improving, they are finding greater acceptance in submersible applications. Lighting may be from quartz iodide, tungsten halogen, mercury-thallium iodide, or mercury vapor sources, with quartz iodide having the most frequent application.

Still camera systems are often used to provide permanent photographic documentation with significantly better resolution than can be obtained with CCTV. Standard 35mm and large format, 70mm cameras are used both singly and in stereo pairs. Strobe lamps supply the illumination. In a few cases, cine cameras are also part of an ROV system, although in most cases real-time viewing on CCTV and recording on videotape, are sufficient.

Other instruments typically found on board an ROV are:

- magnetic compass
- gyro compass
- pressure transducer/depth indicator
- echo sounder/altimeter
- magnetic gradient sensor
- hydrophone
- transponder
- inclinometer
- thermometer
- sub-bottom profiler
- scanning sonar
- side-scan sonar
- capacitance probe
- ultrasonic thickness gauge
- rock drill
- sediment corer
- xenon flasher
- cable cutter
- radiographic flaw detector
- water jet

Vehicle size and umbilical capability, along with mission requirements, determine what combination of instruments shall be mounted on an ROV. The simplest observation vehicles offer little more than a magnetic compass and depth indicator in addition to the CCTV. Other, more sophisticated vehicles have the capability to mount several of the items listed and a configuration that readily allows interchanging of instrument packages.

Remotely operated vehicles without a manipulator are generally limited to observation and inspection tasks. As the level of sophistication of ROVs and manipulator packages increases, more and more work tasks will be performed using an ROV-mounted manipulator. Presently, manipulative tasks account for less than five percent of ROV work accomplished. Manipulators that may be used on an ROV are similar to those employed by manned submersibles except, perhaps, the most powerful ones which would be limited by the thrust/lifting capability of a typical ROV. The simplest package offering some dexterity in underwater task accomplishment is a basic grabber arm. With two functions the grabber arm can extend approximately one foot and open and close the claw. A third function, claw rotation, is also frequently included. These manipulators must rely on the maneuvering ability of the ROV for positioning in two dimensions. More complex manipulators with orientor and locator motions are available and may be fit to an ROV; however, this may prove an expensive option for a functon that is not essential. Additionally, the size and weight of a larger manipulator and its electrohydraulic power unit would require a larger size vehicle for proper deployment. The more advanced manipulator systems may include a work tool package which significantly increases specific task capabilities.

There are some problems in tethered, free-swimming ROV operations. Some are mentioned here, but not all are exclusive to this type of vehicle. Umbilical cable fouling has always been a problem with tethered vehicles, either in the support ship's screws or on a submerged structure. A severed umbilical cable has resulted in the loss of more than one vehicle. The reliability of an active acoustic link is poor around a structure, making the already difficult problem of position location even more so. Most CCTV viewing is still one-dimensional, making interpretation of remote inspection video information difficult. This, in addition to the lack of force feedback during ROV manipulator tasks, makes the operator truly "remote." Operation in shallow water is difficult when surface wave effects and surge are present. A power dip or loss may cause loss of control of the vehicle, resulting in an uncontrolled surfacing and possible damage.

4.2.1.2 Towed ROVs

The second variety of vehicles in this category are the towed systems. This type of system usually consists of a submersible vehicle, tow cable and umbilical, handling system, winch, and control/display station. In order to differentiate these systems from the multitude of towed instrument packages, the inclusion of CCTV is required.

Construction of the vehicle is either open metallic framework or closed fairing for reduced hydrodynamic drag. The average vehicle weight is about 3,000 pounds. Depth capabilities range from 650 feet to 20,000 feet. Towing speed ranges up to 14 knots, but this is highly dependent on mission types. Slower speeds are used when towing close to the bottom. Typical vehicle power requirements are 60 Hz, 115 VAC, 20 amps.

The umbilical is usually electromechanical, providing the vehicle with power, and a data link to the control station, as well as the tow cable connection to the surface ship for vehicle propulsion. Maneuverability of these systems is very limited as the vehicle itself has no propulsive devices.

Approximately 15 towed ROVs are presently in operation with ownership split almost equally between industry and government/academic. Typical instrumentation often includes some combination of the following: CCTV, still camera, sub-bottom profiler, side-scan sonar, obstacle avoidance sonar, directional hydrophone, nephelometer, conductivity meter, temperature and depth sensors, vehicle attitude indicator, sound velocimeter. Some vehicles are incorporating advanced transponder systems for precise navigation, as well as feedback loops from the obstacle avoidance sonar in order to lessen the probability of vehicle damage by collision.

Towed ROVs are generally employed in bottom search or survey-type missions. Several systems are used by the industrial sector in assessing seafloor mineral deposits. Military tasks include search and identification of objects on the bottom, in situ monitoring of munition and hazardous material dumps, bottom surveys, cable route surveys, and seafloor mapping. Research needs have fostered the development of towed ROVs in the academic community, supported primarily with government funds. Missions include seafloor mapping and surveying, micro-bathymetry, high-resolution sub-bottom profiling, and water analysis. No vehicles of this type have manipulators.

In any towed system, problems may be encountered due to surface vessel heave. Various approaches have been taken in attempts to solve this problem in towed ROVs. The winching system can be designed to include accumulators, or the tow cable itself may incorporate a depressor. Alternately, the vehicle may have dynamic control planes coupled with an automatic altitude-keeping device.

4.2.1.3 Bottom Crawling Remotely Operated Vehicles

The final type of tethered ROVs are the bottom-crawling vehicles. A complete system consists of a seabed vehicle, umbilical, handling system and winch, control/display console, and support equipment. These are generally special purpose vehicles, including underwater bulldozers, pipe trenchers, dredgers, and cable burial vehicles. Twelve to fifteen of these vehicles are currently operational. Seabed ROVs are larger than most of the other types of tethered vehicles. The trenching and bulldozing vehicles may weigh up to 200 tons with an average vehicle weight of 54 tons. Cable burial and general purpose vehicles are smaller, with an average weight of about 2 tons. Nearly all vehicles in this class receive surface power via an umbilical. Power requirements for the typical general-purpose vehicle are 440 V, three-phase, 50/60 Hz, while pipe trenching vehicles may require voltages up to 3,300 V. Locomotion is provided either by tracks or wheels moving over the seabed, or by a device using the pipe itself for traction. Depth capabilities of bottom crawlers are generally less than other ROVs.

Instrumentation and tools used on a bottom-crawling vehicle include CCTV, scanning sonar, suction pump, water jets, hydraulic cutters, vehicle attitude sensors, air pressure and hydraulic pressure sensors, gyro, depth gauge, and echo sounder. At least one vehicle of this type is fitted with manipulators.

The size and support requirements of these vehicles are significant and therefore require a dedicated support platform with an experienced crew and extensive inventory of specialized equipment. Based on their large size and specialized mission design, this type vehicle finds little employment in inspection and observation tasks.

4.2.2 Untethered Remotely Operated Vehicles

The number of untethered ROVs is very limited. Presently, less than five such vehicles are operational, with five more undergoing construction or testing. The state-of-the-art is such that major technological breakthroughs are required before the untethered vehicle's work and inspection capabilities will rival those of the existing tethered, free-swimming ROVs. Presently, most vehicles are developmental, with work still required to increase mission duration, incorporate a real-time command control link, and extend overall system flexibility and task capabilities. In most cases, the vehicle is preprogrammed to maintain a certain course, speed, and depth until the next program step. The new course may be initiated by an internal clock or by remote operator via acoustic link. The capabilities of present systems are limited to survey work and oceanographic data sampling. The addition of manipulator work packages is an anticipated development, but not for some time.

Untethered vehicles have some distinct advantages. Development costs may be high, but this is somewhat offset by lower procurement and maintenance costs, since no umbilical or umbilical winch is required. The problems of fouling or breaking an umbilical are not a consideration. The primary disadvantage of an untethered ROV for inspection work is the lack of a high resolution real-time video link. Present systems are further limited by insufficient real-time control functions, as well as relatively short mission endurance capability.

Pioneering work in these areas is being conducted by both the Navy and MIT. Acoustic transmission of video signals has been achieved from depths of 3700 feet by NOSC in San Diego, California. MIT is currently developing an acoustic link real-time control system using a microprocessor encoder and a steered acoustic array with a maximum data rate of up to a few kilobits per second. Within a few years useful systems employing this technology should be available.

4.3 Deployment Method Evaluation

The deployment method evaluation is based on a weighted factor type evaluation matrix. The methods subject to evaluation are as follows:

Manned Systems

- Diver
  - SCUBA
  - Surface Supplied
  - Subsurface Supplied
- Submersible Vehicle
  - Untethered Manned Submersible
  - Tethered Manned Submersible
  - Atmospheric Diving Suit

Unmanned Systems

- Untethered
  - Untethered Remotely Operated Vehicle
- Tethered
  - Observation Remotely Operated Vehicle
  - Work Remotely Operated Vehicle
  - Towed Remotely Operated Vehicle
  - Bottom Crawling Remotely Operated Vehicle

A basic description of each of the deployment methods appears in Sections 4.1 and 4.2. For the purpose of this evaluation, tethered free swimming ROVs have been divided into observation ROVs, and work ROVs, based on the presence or absence of a manipulator. This differentiation is necessary due to significant trade-offs in cost, size, and task capability between some of the vehicles in these two categories.

The deployment methods are evaluated based on their cost, safety, and functional utility, and ability to perform under the environmental conditions as put forth in Section 3.2. The specific evaluation criteria are as follows:

1. Functional Utility

   a. <u>Inspection</u>. The methods are evaluated based on their suitability for marine vessel damage inspection tasks. The facility with which each method can be used to locate the damaged area of a tank vessel and assess the damage is considered.

   b. <u>Plug Delivery</u>. The methods are evaluated on their capacity for delivering any of the Coast Guard hazardous chemical patching and plugging devices (evacuated foam plug, polystyrene foam plug, and air/water inflatable bags). Delivery involves returning to the damaged location, maneuvering the patch/plug into position, and activating the device to form an effective barrier. The prototype devices are configured for manual operation, but the dexterity required for this task is low. Consequently, the efforts required to adapt these devices for remote delivery (e.g., by manipulator) are anticipated to be minimal.

   c. <u>Venting Rate Measurement/Sampling and Analysis</u>. The candidate methods are evaluated on their applicability in making measurements to determine if, and at what rate, a hazardous chemical is leaking from a damaged vessel. In addition, the secondary requirement for a sampling and analysis capability in support of chemical detection, identification, and quantification is considered. As such, the method is judged on its capacity to deploy a chemical sensor package that is approximately one foot in diameter, three feet long and weighs on the order of 75 pounds in air.

   d. <u>Portability</u>. The criteria of portability is evaluated based on total system weight and its capacity to be modularized in order to facilitate rapid delivery from a storage location to the scene of a hazardous chemical incident via Coast Guard vessel, aircraft, or helicopter. Where feasible, a single module should not exceed the carrying capability of two persons.

   e. <u>Set-Up Time</u>. The set-up time to be evaluated for each method, is the time from arrival at the incident scene to the time when the actual mission task work is initiated. This time should be a minimum in order to expedite pollution abatement measures.

2. Safety

a. Risk To Personnel. The candidate methods are evaluated based on the level of risk imposed on the operators. A method that will provide the functional capabilities discussed above, without increasing the hazards imposed on response personnel, is essential. Hardware design should be compatible with, or adaptable to, operation in locations where hazardous concentrations of flammable gases or vapors may exist.

3. Cost

a. Procurement. Procurement cost is evaluated based on the capital investment required to obtain a basic capability in each category. Diving systems are evaluated based on sufficient equipment for three in-water personnel. Submersible vehicle systems shall include, where applicable, submersible vehicle, umbilical and umbilical winch, and control station. In this case, the depth requirement of 50 feet allows consideration of some of the least sophisticated options within some of the deployment method categories, where system complexity and hence, cost, are directly related to depth capability.

b. Support. Evaluation of support costs is based on the costs incurred when equipping, manning, and operating a surface platform for mission duration, as well as such items as gas supplies for divers and manned submersibles, and transportation from storage location to incident scene.

c. Maintenance. Maintenance costs are those required for routine maintenance of the entire system. In addition, consideration is given to increased maintenance costs resulting from operations in a range of hazardous chemical concentrations and how this is affected by system complexity. Interaction with the following category is considered.

d. Adaptation to Hazardous Chemical Environment. The costs evaluated in this category are those incurred during efforts to optimize system compatibility with the hazardous chemicals most likely to be encountered during operation. Such things as specification of chemically resistant materials during construction, or protective measures applied to existing items, are considered. Costs to make hardware safe for operation in the vicinity of flammable gases are also considered.

The Weighted Factor Evaluation is performed in the following manner. A weighting factor is assigned to each of the evaluation criteria based on its relative importance in accomplishing the mission goals cost effectively. A maximum weight factor of 20, indicates a criteria deemed most important, and 1, least important. A Raw Score is then assigned to each deployment method, based on that method's effectiveness in each of the evaluation categories. A Raw Score of 10 (Most Favorable) indicates maximum Functional Utility, maximum Safety, or minimum Cost, and a Raw Score of 1 is a Least Favorable rating. The Raw Score is then multiplied by the appropriate Evaluation Criteria Weighting Factor to obtain the Weighted Score. The Raw Scores and Weighted Scores under each Deployment Method are added to obtain the Total Raw Score and Total Weighted Score. The Total Weighted Scores from each of the separate evaluation sheets are summed and averaged. The Deployment Methods are then ranked according to Average Total Weighted Score, the method with the highest average score being selected by this evaluation method to be the most viable approach. The top three methods are given further consideration. The evaluation sheet, as performed by the R&DC, appears in Figure 4.1. The sources solicited for outside evaluation are listed and the evaluation results presented in Appendix A.

It will be noted that the first three criteria are the functional tasks characteristic of the primary mission requirements. They are included as evaluation criteria and subjected to the same weighted factor approach in order to allow the evaluators to examine the complete spectrum of trade-offs between the basic functional capabilities and the other parameters.

4.4 Deployment Method Evaluation Results

The Deployment Method Evaluation, as conducted, indicates the most promising approach to satisfying the stated mission objectives is through application of a Remotely Operated Vehicle with at least limited work capabilities (e.g., simple grabber or manipulator). The top three methods and their Average Total Weighted Scores from Appendix A are as follows:

1.	Work ROV	878
2.	Observation ROV	783
3.	SCUBA Diver	761

EVALUATION SHEET

DEPLOYMENT METHOD

	CRITERIA	WEIGHT FACTOR	MANNED SYSTEMS: DIVER: SCUBA SCORE RAW	SCUBA SCORE WTD	SURF SUP SCORE RAW	SURF SUP SCORE WTD	SUB SURF SUP SCORE RAW	SUB SURF SUP SCORE WTD	SUBMERSIBLE: UNTETHERED MANNED SUB SCORE RAW	UNTETHERED MANNED SUB SCORE WTD	TETHERED MANNED SUB SCORE RAW	TETHERED MANNED SUB SCORE WTD	ADS SCORE RAW	ADS SCORE WTD
FUNCTIONAL UTILITY	Inspection	13	10	130	10	130	10	130	8	104	6	78	9	117
	Plug Deployment	12	10	120	10	120	10	120	7	84	6	72	9	108
	Vent Rate Meas.	10	9	90	9	90	9	90	8	80	7	70	9	90
	Portability	6	10	60	7	42	2	12	2	12	2	12	7	42
	Set Up Time	6	10	60	8	48	4	24	3	18	3	18	7	42
SAFETY	Risk To Pers.	20	1	20	2	40	2	40	4	80	5	100	5	100
COST	Procurement	6	10	60	9	54	4	24	2	12	4	24	7	42
	Support	8	10	80	8	64	4	32	3	24	2	16	7	56
	Maintenance	8	10	80	8	64	4	32	2	16	2	16	7	56
	Adapt. to Haz. Chem.	6	2	12	4	24	1	6	1	6	1	6	6	36
	TOTAL		82	712	75	676	50	510	40	436	38	412	73	689

	CRITERIA	WEIGHT FACTOR	UNMANNED SYSTEMS: UNTETHERED: UNTETHERED ROV SCORE RAW	UNTETHERED ROV SCORE WTD	OBSERVATION ROV SCORE RAW	OBSERVATION ROV SCORE WTD	TETHERED: WORK ROV SCORE RAW	WORK ROV SCORE WTD	TOWED ROV SCORE RAW	TOWED ROV SCORE WTD	BOTTOM CRAWLING ROV SCORE RAW	BOTTOM CRAWLING ROV SCORE WTD
FUNCTIONAL UTILITY	Inspection	13	2	26	8	104	8	104	3	39	2	26
	Plug Deployment	12	1	12	2	24	8	96	2	24	3	36
	Vent Rate Meas.	10	2	20	6	60	8	80	2	20	1	10
	Portability	6	4	24	8	48	7	42	7	42	2	12
	Set Up Time	6	2	12	8	48	7	42	7	42	4	24
SAFETY	Risk To Pers.	20	10	200	10	200	10	200	10	200	10	200
COST	Procurement	6	5	30	8	48	7	42	9	54	3	18
	Support	8	6	48	9	72	8	64	8	64	4	32
	Maintenance	8	5	40	8	64	7	56	8	64	4	32
	Adapt. to Haz. Chem.	6	7	42	10	60	9	54	10	60	2	12
	TOTAL		44	460	77	728	79	780	66	609	35	402

Evaluation Performed By: USCG R&D Center (R. Walker)

Date: 1/21/80

Key:

Weight Factor:
20 - Most Important
1 - Least Important

Raw Score:
10 - Most Favorable
1 - Least Favorable

FIGURE 4.1

The second highest score went to Observation Remotely Operated Vehicles which suffered primarily in the functional area of plug deployment. This category was followed closely by Scuba Diver which has superior ranking in both functional utility and cost criteria, but has most significant drawbacks in the level of risk imposed on underwater personnel. This result supports the approach of using SCUBA divers as an efficient and cost-effective means of accomplishing damage inspection, venting rate measurement, and patch/plugging tasks when the nature of the leaking substance is not sufficiently hazardous to prevent underwater operations by Coast Guard personnel. Results of the work currently in progress at NCSC in the area of protective diving suits for use in polluted waters could be a significant step toward extending the diver's capability to work in spill situations. For those instances where safety considerations, due to the presence of a hazardous chemical, preclude the use of SCUBA Divers, a Remotely Operated Vehicle is the most efficient, cost-effective, and safest method for accomplishing these tasks. Therefore, the category of SCUBA Diver is a deployment method that may be used with discretion in some spill response activities once it has been determined that there is no significant level of risk to the diver or his life support equipment due to the nature of a spilled material. As this is a current Coast Guard capability, further study is not warranted here. For instances in which the Coast Guard is not presently able to respond due to the presence of a highly hazardous underwater environment, further evaluation of the alternatives in remote delivery hardware is justified. Vehicles falling in the two top-ranked deployment method categories are given further consideration in the following section.

5.0 REMOTELY OPERATED VEHICLES: WORK AND OBSERVATION SYSTEMS

5.1 Work ROVs

Based on the results of the Deployment Method Evaluation, a state-of-the-art survey of remotely operated underwater vehicles was conducted. Work ROVs represent the largest number of vehicles in this category. Data has been compiled and is presented here on a total of 26 such vehicles. Photographs of each vehicle are provided where available. In addition, 6 vehicles were included under a sub-category of "Manipulator Optional ROVs" representing a class of vehicles that may operate with or without an optional manipulator arm. The data compiled on the vehicles are as follows:

Depth: Maximum safe operating depth, in feet of sea water.

Dimensions (LxWxH): The length, width, and height of the vehicle in inches.

Weight: The vehicle dry weight in pounds. Systems using an underwater launcher or clump are so noted, and launcher weight is given where available.

Speed (Max Surface): Maximum speed of the vehicle when operating at or near the surface, in knots.

Speed (Max Current): Maximum current (usually at maximum depth) that a vehicle can effectively work and hold position in, given in knots.

Structure: Basic description of the vehicle's structure and buoyancy mode.

Propulsion: Description, including number and orientation, of thruster devices.

Instrumentation: Listing of standard and optional equipment that may be mounted on the vehicle. DOF indicates the degrees of freedom of a manipulator.

Power Req: Power requirements for system operation.

Shipboard Components: Listing of system components that remain on surface platform during operation.

Support Vessel Req: Support vessel requirements, including deck space, power source, lifting capability, etc.

Crew: Number of personnel necessary for vehicle deployment and operation; may increase with mission duration.

Total Shipping Vol: Volume required in order to ship entire system.

Total Shipping Weight: Shipping weight of entire system.

Builder: Commercial company or organization responsible for ROV system development.

In all cases, an entry of NA indicates the data was not available.

The data on Work and Manipulator Optional ROVs is presented in Appendix B.

5.2 Observation Remotely Operated Vehicles

Data was compiled on twelve different observation ROVs. Two additional vehicles were identified in a sub-category of Ship Husbandry Vehicles. These vehicles are designed specifically for vessel hull inspection and cleaning, and are included for that reason. These vehicles are propelled by traction wheels bearing on the vessel's hull, rather than free-swimming with thruster propulsion. SCAMP, one of the vehicles in this category, is the only vehicle for which information was compiled that does not include a TV camera for inspection purposes.

The data on Observation and Ship Husbandry Vehicles is presented in Appendix C.

5.3 Evaluation of ROVs

The evaluation and ranking of specific vehicles within the Work and Observation ROV categories is based on two main factors. The vehicles are first ranked by increasing vehicle weight as shown in Tables 5-1 and 5-2. This number was found to be consistently reliable, a good indicator of vehicle portability, and a reasonable indicator of vehicle complexity which has implications in Support, Maintenance, and Adaptation to Hazardous Chemical Environment Costs. Shipping Weight and Shipping Volume data are also included for reference, where available. However, this data was not used as a ranking factor due to unreliability and lack of information as to what was included in the "system" in order to arrive at these figures.

In order to insure portability and to maximize "vessel of opportunity" deployment, a vehicle weight of approximately 500 pounds was selected as a reasonable upper limit. This weight is representative of a vehicle that can be handled with current Coast Guard Strike Team resources and requires minimal surface vessel handling gear; in most cases, a simple boat davit would be sufficient.

For the vehicles that passed this level screening, procurement cost data was obtained. This information represents approximate budgetary prices which are current as of January 1980. Prices attached to the Snoopy vehicles are construction cost estimates made by Naval Ocean System Center (San Diego) personnel.

TABLE 5-1

WORK AND MANIPULATOR OPTIONAL ROVs: WEIGHT RANKING

ROV	VEHICLE WEIGHT (pounds)	SHIP WEIGHT (pounds)	SHIP VOLUME (cubic feet)
EV-1	250	1,400	52.5
SEA INSPECTOR	309	NA	NA
RECON III	380	1,850	136.0
TREC	450	1,000	120.0
PHOCAS II	500	NA	NA
TELESUB 1000	550	1,060	38.4
RECON II	650	2,100*	65.8
CORD I	720	9,800	132.5
RECON V	850	2,050	136.0
RCV-150	1,000	26,000	252.0*
SCORPIO	1,500	10,000	600.0
SMIT SUB-1000	1,500	62,380	4,573.0
MURS-100	1,984	10,000	989.0
CETUS	2,000	NA	1,655.0
BOCTOPUS	2,140	25,000	2,154.0
MANTA 1.5	2,200	8,000	706.0
SMT.1	2,200	6,125	NA
SNURRE II	2,500	22,000	NA
CUTLET	2,536	NA	NA
TROV 5	3,300	5,200	NA
CURV II	3,450	52,000*	4,500.0
RECON VI	3,900	NA	NA
CURV III	4,000	52,000*	4,500.0
SCARAB	5,000	74,000	NA
MURS-300	5,291	NA	2,553.0
ORCA 1	6,000	26,000*	NA
ERIC 1	6,160	NA	NA
ERIC 10	6,200	22,000	1,588.0
CONSUB 2	6,373	39,374	1,624.0
TOM 300	6,600	30,800	1,483.0
SPIDER	7,000	NA	1,280.0
RUWS	7,000	164,000	NA
ERIC II	11,000	104,800	7,838.0
TRUCS	12,000	NA	NA

*Optional support equipment not included in this figure.

TABLE 5-2

OBSERVATION ROVs: WEIGHT RANKING

ROV	VEHICLE WEIGHT (pounds)	SHIP WEIGHT (pounds)	SHIP VOLUME (cubic feet)
DART	100	250	10
ELECTRIC SNOOPY	159	1,200	100
FILIPPO	180	280	15
RCV 225	180	5,555	285
SMARTIE	181	NA	NA
SEA SPY	225	600	17
IZE	300	NA	NA
NAVFAC SNOOPY	475	1,370	111
SCAN	NA	NA	NA
SCAMP	1,500	NA	NA
DEEP DRONE	1,500	11,000	4,000
ANGUS 002	1,540	7,000	783
ANGUS 003	2,200	NA	NA
CONSUB 1	3,000	6,100	NA

Evaluation based on the specific functional utility criteria, as laid out in the Deployment Method Evaluation approach, was not appropriate here for the following reasons:

Inspection: All vehicles considered in detail have inspection capabilities using CCTV. In all cases, a still photography camera could easily be added if it is not included in the standard instrumentation package.

Plug Delivery: At this level of evaluation, the delivery capability evaluation is simply based on the presence (standard or optional) or absence of some type of manipulator or grabber arm. This distinction has been made in the major categorical groupings of Work and Observation Vehicles.

Portability: This criterion is addressed by the vehicle weight ranking.

Set-Up Time: There is insufficient information in this area to use for the evaluation.

There are six Work ROVs and eight Inspection ROVs that fall near or below the maximum weight limit of 500 pounds. Those vehicles that meet the weight requirement are then ranked by increasing Procurement Cost. The results of this ranking are presented in Tables 5-3 and 5-4 for Work and Observation ROVs, respectively.

TABLE 5-3

WORK ROV: COST RANKING

ROV	COST ($K-JANUARY 1980)
TREC	115
EV-1	120
RECON III	151
TELESUB - 1000	225
SEA INSPECTOR	358
PHOCUS II	NA

TABLE 5-4

OBSERVATION ROV: COST RANKING

ROV	COST ($K-JANUARY 1980)
DART	50
FILIPPO	56
RCV-225	200
ELECTRIC SNOOPY	250-350
NAVFAC SNOOPY	350-400
SMARTIE	Charter only
SEA SPY	NA
IZE	NA

6.0 CONCLUSIONS

This report is a study of methods that might be used in accomplishing three specific tasks when responding to a hazardous chemical spill originating from a tank vessel or barge in the marine environment. These tasks are:

1. Damage inspection of the endangered vessel.

2. Delivery of Coast Guard hazardous chemical patching and plugging devices (e.g., polystyrene foam plug, evacuated foam plug, air/water inflatable bags).

3. Delivery of a chemical sensor for venting rate measurements, sampling, and analysis for the detection, identification, and quantification of hazardous chemical pollutants.

Mission requirements and design goals are established and are presented in Section 3. Based on these requirements, all possible deployment methods are reviewed and subjected to a weighted factor evaluation in Section 4. This evaluation is based on functional utility, safety, and cost criteria. The top three methods indicated by this evaluation are as follows:

1. Work Remotely Operated Vehicle
2. Observation Remotely Operated Vehicle
3. SCUBA Diver

The third category, SCUBA Diver, excels in all areas of functional utility and shows considerable savings in all but one cost criterion. This method suffers mainly from the level of risk imposed on the divers. This problem is being addressed by work such as that being conducted at NCSC to develop a dry suit for use by divers in polluted waters. Since SCUBA Diving represents a current Coast Guard capability and presently has a limited application in hazardous chemical spill response activities, it is not given further consideration.

The Deployment Method Evaluation indicates the most promising approach to satisfying the stated mission objectives is through the application of a Remotely Operated Vehicle (ROV), with at least limited work capabilities, using a simple grabber arm or manipulator. For inspection capabilities, the simpler, and typically smaller, Observation ROV is most suitable. While lacking in certain functional areas, this type ROV represents a reasonable alternative for consideration in the cost/capability trade-off analysis.

More detailed information on specific vehicles within the top two categories is presented in appendices B and C. ROVs within each category are evaluated and ranked according to portability, and cost. A vehicle weight of approximately 500 pounds is used as an upper limit. ROVs weighing in excess of this figure are not ranked. The results of the rank ordering are as follows:

ROV	BUILDER	APPROX COST ($K-JAN 1980)
	WORK ROVS	
1) TREC	I.S.E. Port Moody, B.C. (Canada)	115
2) EV-1	Kraft Tank Company Kansas City, MO	120
3) RECON III	Perry Oceanographics Riviera Beach, FL	151
4) Telesub 1000	Remote Ocean Systems Escondido, CA	225
5) SEA INSPECTOR	Rebikoff Underwater Products Fort Lauderdale, FL	358
	OBSERVATION ROVS	
1) DART	I.S.E. Port Moody, B.C. (Canada)	50
2) FILIPPO	Nereides Orsay, France	56
3) RCV-225	Hydro Products San Diego, CA	200
4) Electric Snoopy	NOSC San Diego, CA	250-350
5) Navfac Snoopy	NOSC San Diego, CA	350-400
6) SMARTIE	Marine Unit Technology Ltd. Surrey, England	Charter only
7) SEA SPY	Underwater and Marine Equipment Ltd. Hampshire, England	NA
8) IZE	Sub Sea Surveys, Ltd. Cambria, England	NA

One comment is in order with regard to the Work ROV, SEA INSPECTOR. In the design of this vehicle, dive planes are used to control vertical movement, making pure vertical motion unfeasible. As such, inspection of a vessel hull would have to be conducted using horizontally oriented scan lines.

REFERENCES

(1) U.S. Coast Guard, "Polluting Incidents In and Around U.S. Waters - Calendar Year 1978," COMDINST M16450.2, 1979.

(2) Christensen, R.D., and D.L. Motherway, "Survey Update on Damage Assessment and State-of-the-Art of Patching and Plugging Systems," Interim Report. U.S. Coast Guard Research and Development Center, Groton, CT, December 1978.

(3) Maritime Administration/U.S. Coast Guard, "Tank Barge Study," Joint Study, December 1974.

(4) National Fire Protection Association, "National Fire Codes-1978," Volume 4, Boston, MA, 1978.

(5) U.S. Navy, "U.S. Navy Diving Manual," NAVSEA 0994-LP-001-9010, Washington, DC, December 1975.

(6) R. Frank Busby Associates, Inc., "Remotely Operated Vehicles," prepared for U.S. Department of Congress and NOAA, August 1979.

APPENDIX A

DEPLOYMENT METHOD EVALUATION DATA

Input to the Deployment Method Evaluation screening was solicited from personnel within various operational and research sectors of the Navy. The following sources were specifically selected in hopes that they would provide meaningful information based on their experience and extensive knowledge of the deployment methods in question.

1. Mr. Ron Duddleston
   Deep Submergence Systems Project Manager (NC 3)
   Naval Sea Systems Command
   Code PMS 395
   Alexandria, VA 22306

2. Mr. Howard Talkington
   Ocean Technology Department Chief
   Naval Ocean Systems Center (Code 52)
   San Diego, CA 92132

3. Mr. Dale Uhler
   Director of Ocean Engineering Supervisor of Diving (CM 2)
   Naval Sea Systems Command Code (OOC)
   Alexandria, VA 22306

4. Mr. L. F. Walker
   Naval Coastal Systems Center (Code 713)
   Panama City, FL 32407

The participants were each mailed a Deployment Method Evaluation package which contained the following enclosures:

1. Deployment Method Evaluation Sheet
2. Representative List of Hazardous Chemicals
3. 1 copy of "U.S. Coast Guard Leak Plugging Device"
4. 1 copy of "Vessel Damage Plugging Device Development Test and Evaluation"

The forwarding letter included a narrative describing the mission requirements, evaluation criteria, and a brief description of each of the deployment methods to be evaluated. Based on this and the hardware descriptions and list of chemicals in the enclosures, the participants were asked to perform a weighted factor evaluation of those methods listed. The results of this evaluation survey are presented in figures A-1 through A-4. The Average Total Weighted Scores given in figure A-5 were obtained by adding the individual Total Weighted Scores for each of the Deployment Methods and then averaging. These results are then used to obtain a rank ordering of the Deployment Methods considered.

EVALUATION SHEET

DEPLOYMENT METHOD

		MANNED SYSTEMS												UNMANNED SYSTEMS									
		DIVER								SUBMERSIBLE				UNTETHERED				TETHERED					
CRITERIA		SCUBA		SURF SUP		SUB SURF SUP		UNTETHERED MANNED SUB		TETHERED MANNED SUB		ADS		UNTETHERED ROV		OBSERVATION ROV		WOPY ROV		TOWED ROV		BOTTOM CRAWLING ROV	
	WEIGHT FACTOR	SCORE RAW	SCORE WTD	SCORE RAW	SCORE WTD	SCORE RAW	SCORE WTD	SCORE RAW	SCORE WTD	SCORE RAW	SCORE WTD	SCORE RAW	SCORE WTD	SCORE RAW	SCORE WTD	SCORE RAW	SCORE WTD	SCORE RAW	SCORE WTD	SCORE RAW	SCORE WTD	SCORE RAW	SCORE WTD
FUNCTIONAL UTILITY: Inspection	14	9	126	9	126	9	126	5	70	5	70	3	42	9	126	10	140	9	126	3	42	1	14
Plug Deployment	12	10	120	10	120	10	120	5	60	5	60	3	36	7	84	1	12	7	84	3	36	1	12
Vent Rate Meas.	2	10	20	10	20	10	20	5	10	5	10	3	6	7	14	7	14	7	14	3	6	1	2
Portability	16	9	144	7	112	3	48	2	32	2	32	2	32	6	96	6	96	6	96	6	96	7	112
Set Up Time	8	8	64	6	48	3	24	2	16	2	16	2	16	5	40	5	40	5	40	5	40	7	56
SAFETY: Risk To Pers.	20	2	40	2	40	2	40	8	160	8	160	7	140	10	200	10	200	10	200	10	200	10	200
COST: Procurement	18	5	90	4	72	3	54	2	36	2	36	3	54	4	72	4	72	3	54	3	54	3	54
Support	10	5	50	4	40	3	30	2	20	2	20	3	30	4	40	4	40	3	30	3	30	3	30
Maintenance	16	5	80	4	64	3	48	2	32	2	32	3	48	4	64	4	64	3	48	3	48	3	48
Adapt to Haz. Chem.	6	1	6	1	6	1	6	7	42	7	42	5	30	7	42	7	42	7	42	7	42	7	42
TOTAL		64	940	57	648	47	516	40	478	40	478	34	434	63	778	58	720	60	866	46	600	43	570

Evaluation Performed By: NAVSEA

Date:

Key:

Weight Factor:
20 - Most Important
1 - Least Important

Raw Score:
10 - Most Favorable
1 - Least Favorable

Enclosure (1)

FIGURE A.1

EVALUATION SHEET

DEPLOYMENT METHOD

	CRITERIA	WEIGHT FACTOR	MANNED SYSTEMS												UNMANNED SYSTEMS									
			DIVER								SUBMERSIBLE				UNTETHERED				TETHERED					
			SCUBA		SURF SUP		SUB SURF SUP		UNTETHERED MANNED SUB		TETHERED MANNED SUB		ADS		UNTETHERED ROV		OBSERVATION ROV		WORK ROV		TOWED ROV		BOTTOM CRAWLING ROV	
			SCORE		SCORE		SCORE		SCORE		SCORE		SCORE		SCORE		SCORE		SCORE		SCORE		SCORE	
			RAW	WTD	RAW	WTD	RAW	WTD	RAW	WTD	RAW	WTD	RAW	WTD	RAW	WTD	RAW	WTD	RAW	WTD	RAW	WTD	RAW	WTD
FUNCTIONAL UTILITY	Inspection	10	7	70	7	70	7	70	6	60	6	60	7	70	8	80	9	90	9	90	5	50	6	60
	Plug Deployment	20	4	80	4	80	4	80	5	100	5	100	4	80	5	100	4	80	9	180	5	100	8	160
	Vent Rate Meas.	10	5	50	5	50	5	50	5	50	5	50	4	40	6	60	6	60	6	60	5	50	6	60
	Portability	15	7	105	5	75	5	75	4	60	4	60	6	90	8	120	7	105	7	105	6	90	7	105
	Set Up Time	15	7	105	5	75	5	75	4	60	4	60	6	90	8	120	7	105	7	105	6	90	7	105
SAFETY	Risk to Pers.	15	1	15	3	45	3	45	6	90	6	90	6	90	10	150	9	135	9	135	9	135	9	135
COST	Procurement	10	8	80	6	60	4	40	2	20	2	20	5	50	8	80	9	90	8	80	7	70	7	70
	Support	15	5	75	5	75	4	60	2	30	2	30	5	75	7	105	7	105	7	105	6	90	6	90
	Maintenance	10	5	50	5	50	4	40	2	20	2	20	5	50	7	70	7	70	7	70	6	60	6	60
	Adapt to Haz. Chem.	10	1	10	3	30	3	30	6	60	6	60	6	60	10	100	10	100	10	100	9	90	9	90
	TOTAL		50	640	48	610	44	565	42	550	42	550	54	615	77	985	75	940	79	1030	64	925	71	935

Evaluation Performed By: NOSC

Date:

Key:

Weight Factor:
20 - Most Important
1 - Least Important

Raw Score:
10 - Most Favorable
1 - Least Favorable

Enclosure (1)

FIGURE A.2

EVALUATION SHEET

DEPLOYMENT METHOD

CRITERIA	WEIGHT FACTOR	MANNED SYSTEMS – DIVER – SCUBA RAW	SCUBA WTD	SURF SUP RAW	SURF SUP WTD	SUB SURF SUP RAW	SUB SURF SUP WTD	MANNED SYSTEMS – SUBMERSIBLE – UNTETHERED MANNED SUB RAW	UNTETHERED MANNED SUB WTD	TETHERED MANNED SUB RAW	TETHERED MANNED SUB WTD	ADS RAW	ADS WTD	UNMANNED SYSTEMS – UNTETHERED – UNTETHERED ROV RAW	UNTETHERED ROV WTD	OBSERVATION ROV RAW	OBSERVATION ROV WTD	UNMANNED SYSTEMS – TETHERED – WORK ROV RAW	WORK ROV WTD	TOWED ROV RAW	TOWED ROV WTD	BOTTOM CRAWLING ROV RAW	BOTTOM CRAWLING ROV WTD
FUNCTIONAL: Inspection	20	7	140	10	200	10	200	3	60	2	40	1	20	3	60	6	120	6	120	1	20	1	20
Plug Deployment	18	7	126	10	180	10	180	3	54	3	54	2	36	1	18	1	18	3	54	1	18	1	18
Vent Rate Meas.	5	3	15	4	20	4	20	3	15	3	15	2	10	1	5	1	5	5	25	1	5	1	5
Portability	15	10	150	8	120	7	105	1	15	1	15	1	15	2	30	6	90	6	90	6	90	2	30
Set Up Time	15	10	150	8	120	7	105	1	15	1	15	1	15	3	45	6	90	6	90	6	90	2	30
SAFETY: Risk to Pers.	20	1	20	2	40	2	40	6	120	5	100	5	100	10	200	10	200	10	200	10	200	10	200
COST: Procurement	5	10	50	9	45	8	40	1	5	1	5	3	15	1	5	7	35	6	30	5	25	3	15
Support	10	10	100	9	90	8	80	1	10	1	10	3	30	6	60	7	70	7	70	7	70	6	60
Maintenance	10	10	100	9	90	8	80	1	10	1	10	2	20	2	20	7	70	7	70	7	70	5	50
Adapt to Haz. Chem.	20	1	20	2	40	2	40	5	100	5	100	5	100	5	100	5	100	5	100	5	100	5	100
TOTAL		69	871	71	945	66	890	25	404	23	364	25	361	34	543	56	798	61	844	44	68[illegible]	36	528

Evaluation Performed By: NAV[illegible] (D. [illegible])

Date: [illegible]

Key:

Weight Factor:
20 - Most Important
1 - Least Important

FIGURE A.3

EVALUATION SHEET

DEPLOYMENT METHOD

	CRITERIA	WEIGHT FACTOR	MANNED SYSTEMS												UNMANNED SYSTEMS									
			DIVER								SUBMERSIBLE				UNTETHERED				TETHERED					
			SCUBA		SURF SUP		SUB SURF SUP		UNTETHERED MANNED SUB		TETHERED MANNED SUB		ADS		UNTETHERED ROV		OBSERVATION ROV		WORK ROV		TOWED ROV		BOTTOM CRAWLING ROV	
			SCORE		SCORE		SCORE		SCORE		SCORE		SCORE		SCORE		SCORE		SCORE		SCORE		SCORE	
			RAW	WTD	RAW	WTD	RAW	WTD	RAW	WTD	RAW	WTD	RAW	WTD	RAW	WTD	RAW	WTD	RAW	WTD	RAW	WTD	RAW	WTD
FUNCTIONAL UTILITY	Inspection	15	9	135	9	135	9	135	6	90	6	90	9	135	7	105	8	120	8	120	3	45	1	15
	Plug Deployment	20	10	200	9	180	9	180	5	100	5	100	6	120	8	160	1	20	8	160	1	20	1	20
	Vent Rate Meas.	3	10	30	9	27	9	27	7	21	7	21	6	18	8	24	1	3	8	24	7	21	1	3
	Portability	10	10	100	8	80	6	60	3	30	3	30	3	30	6	60	7	70	6	60	5	50	6	60
	Set Up Time	12	10	120	9	108	8	96	6	72	6	72	6	72	6	72	6	72	6	72	5	60	6	72
SAFETY	Risk To Pers.	18	1	18	1	18	1	18	3	54	3	54	3	54	9	162	9	162	9	162	9	162	9	162
COST	Procurement	5	9	40	7	35	7	35	3	15	3	15	4	20	2	10	6	30	5	25	6	30	4	20
	Support	10	9	90	8	80	6	60	4	40	4	40	5	50	4	40	5	50	5	50	5	50	4	40
	Maintenance	10	9	90	7	70	6	60	4	40	4	40	4	40	1	10	6	60	5	50	5	50	4	40
	Adapt to Haz. Chem.	18	1	18	1	18	1	18	5	90	5	90	4	72	8	144	8	144	8	144	8	144	8	144
	TOTAL		78	841	68	751	62	639	46	552	46	532	50	611	59	787	57	731	68	867	54	632	44	576

Evaluation Performed By: L.F. Walker
U.S. Naval Coastal Systems Center
Code 751
Panama City, Fla 32401
(904) 234-4474

Date: 2/8/80

Key:

Weight Factor:
20 - Most Important
1 - Least Important

Raw Score:
10 - Most Favorable
1 - Least Favorable

Enclosure (1)

FIGURE A.4

EVALUATOR	MANNED SYSTEMS						UNMANNED SYSTEMS				
	DIVER				SUBMERSIBLE		UNTETHERED		TETHERED		
	SCUBA	SURF SUP	SUB SURF SUP	UNTETHERED MANNED SUB	TETHERED MANNED SUB	ADS	UNTETHERED ROV	OBSERVATION ROV	WORK ROV	TOWED ROV	BOTTOM CRAWLING ROV
	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE
CGR&DC	712	676	510	436	412	689	460	728	780	609	402
NAVSEA	740	648	516	478	478	434	778	720	866	600	570
NOSC	640	610	565	550	550	695	985	940	1030	825	935
NAVSEA	871	945	890	404	364	361	543	798	849	688	528
NCSC	841	751	639	552	552	611	787	731	867	632	576
GRAND TOTAL WEIGHTED SCORE	3804	3630	3120	2420	2356	2790	3553	3917	4392	3354	3011
AVERAGE TOTAL WEIGHTED SCORE	761	726	624	484	471	558	711	783	878	671	602

FIGURE A.5

DEPLOYMENT METHOD EVALUATION SUMMARY

APPENDIX B

WORK AND MANIPULATOR OPTIONAL ROV SPECIFICATIONS

CETUS
(Computerized Exploration and Technical Underwater Surveyor)

DEPTH: 1,500'
DIMENSIONS (LxWxH): 96" x 60" x 48"
WEIGHT: 2,000 lbs

SPEED: (Max Surface) 4.2 kts
(Max Current) 1.6 kts @ max depth
STRUCTURE: Rectangular, open aluminum framework encloses and supports all components. Positive buoyancy is provided by syntactic foam blocks. Two trim tanks provide up to 420 lbs variable buoyancy.

PROPULSION: Four electric thrusters (2 long, 1 vert, 1 lat). All are 4.3 hp, 940 rpm, 415V, 3Ø, variable pitch control.

INSTRUMENTATION: CCTV (1 fixed for pilot, 1 on pan and tilt (p&t) for observer), 35mm still camera, mag compass, gyro, echo sounder, pressure transducer, magnetic gradiometer. Two manipulators with four degrees-of-freedom (DOF), 36" extension, 200 lbs max load at max extension. Long and short baseline navigation systems.

POWER REQ: 415V, 50Hz, 3Ø or 498V, 60Hz, 3Ø

SHIPBOARD COMPONENTS: Control cabin, optional diesel generator, cable winch.

SUPPORT VESSEL REQ: Launch/retrieval crane, 1,679 sq ft deck space.

CREW: Four (12 hrs), nine (24 hrs)
TOTAL SHIPPING VOL: Approx 1,655 cu ft

TOTAL SHIPPING WEIGHT: NA

BUILDER: ULS Marine Ltd, Gloucester, England

CORD 1
(Cabled Observation and Rescue Device)

DEPTH: 1500'
DIMENSIONS (LxWxH): 68" x 41" x 55"
WEIGHT: 720 lbs, plus up to 50 lbs payload

SPEED: (Max Surface) 5 kts
(Max Current) 2 kts @ max depth

STRUCTURE: A U-shaped 10" diameter tube provides flotation and houses most of the electronics. The vehicle base consists of two rectangular oil-filled pads which serve as hydraulic reservoirs and mounting locations for components. ±15 lbs buoyancy may be provided by varying volume of oil in soft bladder.

PROPULSION: Four fixed, reversible props driven by a 3 hp hydraulic motor (2 long, 1 lat, 1 vert), all with continously variable speed control.

INSTRUMENTATION: Low light CCTV and light on p&t, 70mm wide angle still camera with strobe, current speed sensor, temp sensor, echo sounder, mag compass, depth sensor, obstacle avoidance sonar. Hydraulically powered manipulator with 2 DOF, scissors-type claw.

POWER REQ: 480V, 60Hz, 3Ø, 5KW

SHIPBOARD COMPONENTS: Sea Guardian (vehicle's support craft) has all controls for CORD's operation. 115 hp diesel drives three hydrualic pumps which power the main hydrostatic transmission propulsion system, a 5KW alternator, bow and stern thrusters, line hauler, and storage reel. Vessel has dynamic positioning system.

SUPPORT VESSEL REQ: Sea Guardian is 23' long with 9' beam. Loaded weight is 4.5 tons. Presently is the only vehicle capable of deploying CORD.

CREW: 3
TOTAL SHIPPING VOL: Approx 1,325 cu ft

TOTAL SHIPPING WEIGHT: Approx 4.9 tons

BUILDER: Harbor Branch Foundation, Inc., Ft. Pierce, FL

CONSUB 201 and 202

DEPTH: 2000'
DIMENSIONS (LxWxH): 145" x 85" x 69"
WEIGHT: 6,393 lbs

SPEED: (Max Surface) 2.5 kts
(Max Current) 2 kts @ max depth

STRUCTURE: Rectangular, air-filled Al alloy (HE130) framework encloses and supports all components. Modular synthetic foam atop framework adjusted to give 50 lbs positive buoyancy.

PROPULSION: Four fixed, reversible, 12.5 hp electric thrusters with Kort nozzles (2 long, 1 lat, 1 vert). Control by differential adjustment of thrusters, which provide up to 700 lbs static thrust each.

INSTRUMENTATION: Two CCTV cameras and stereo still cameras all mounted on p&t unit. Additional CCTV on pan unit for pilot. Depth sensor, mag compass, side-scan sonar, magnetic tracker, sub-bottom profiler, echo sounder, c-p probes, nine 1,000 W quartz iodide lights, manipulator, self-powered transponder & emergency flasher for recovery.

POWER REQ: 380/415/440V, 50/60Hz, 3Ø, 125KVA (to control cabin transformer)

SHIPBOARD COMPONENTS: Control console, transformer, system distribution box (connects transformer, ship junction box, and consoles), ship junction box, and cable winch.

SUPPORT VESSEL REQ: Deck space: 15' x 18.4' for vehicle, 20' x 6.5' for cable winch. Crane with 6.5' reach rated for 6,400 lbs minimum. Two cabins 19.7' x 8' x 8.5' each. Stationkeeping requirements dependent on current speed and vehicle depth.

CREW: 4

TOTAL SHIPPING VOL: 1,624 cu ft plus diesel generator if required

TOTAL SHIPPING WEIGHT: 39,374 lbs

BUILDER: British Aircraft Corp., Bristol, England

COMMENTS: Vehicle control system can be used in three ways. The "camera stabilization mode" automatically controls thrusters to propel vehicle in constant compass bearing of pilot TV viewing axis. The "frame stabilization mode" automatically locks frame to pilot's camera with constant relative bearing which is maintained during vehicle progress. Pilot may also operate in standard manual mode. Vehicle is designed for maximum flexibility in accepting various payload components.

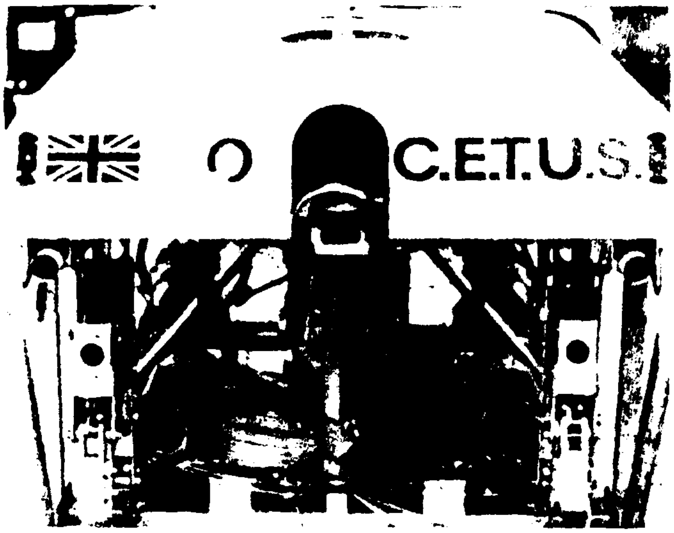


FIGURE B.1 - CETUS
Courtesy of: ULS Marine Limited

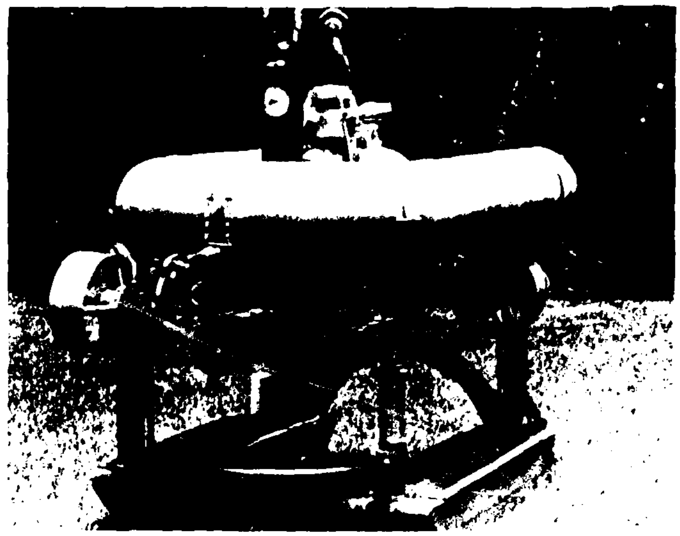


FIGURE B.2 - CORD I
Courtesy of: Harbor Branch Foundation

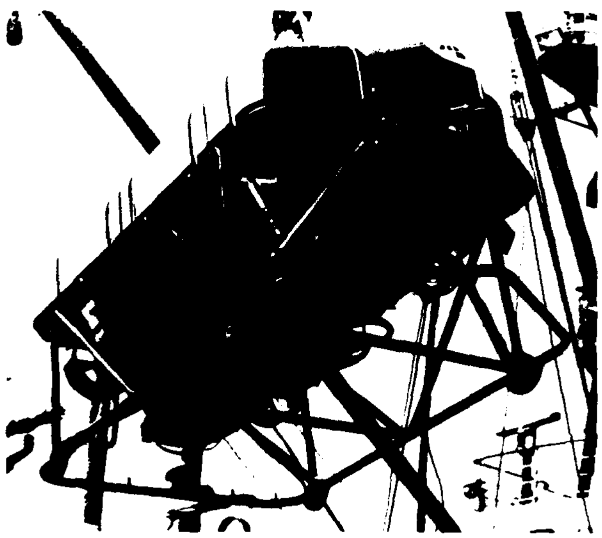


FIGURE B.3 - CONSUB 201
Courtesy of: Sub Sea Surveys

CURV II

DEPTH: 2,500'
DIMENSIONS (LxWxH): 180" x 72" x 72"
WEIGHT: 3,450 lbs

SPEED: (Max Surface) 4 kts
(Max Current) NA

STRUCTURE: Rectangular-shaped open Al framework encloses and supports all components. Synthetic foam blocks affixed to top of framework are adjusted for slightly positive buoyancy.

PROPULSION: Three 10 hp, 440 VAC electric motors power three propellers, all capable of independent operation. Two provide forward-reverse thrust, one provides vertical motion.

INSTRUMENTATION: Two CCTV cameras, 35mm still camera, lights, altimeter, depthometer, mag compass, active and passive CTFM sonar, hydraulically powered manipulator with 3 DOF, circular-type (torpedo grasping) claw.

POWER REQ: 400VAC, 120VAC, 3Ø, 50KW. All power supplied by portable 60KW diesel generator.

SHIPBOARD COMPONENTS: Portable van with remote console, generator, and conversion equipment, launch/retrieval system.

SUPPORT VESSEL REQ: Stationkeeping capability and cable handling away from screws. Deck space for seven items approximately 75 to 120 sq ft each.

CREW: 7, 10 in emergency mission
TOTAL SHIPPING VOL: 4,500 cu ft plus handling crane, if necessary

TOTAL SHIPPING WEIGHT: 26 tons plus crane

BUILDER: Naval Ocean System Center, San Diego, CA

CURV III

DEPTH: 10,000'
DIMENSIONS (LxWxH): 150" x 78" x 78"
WEIGHT: 4,000 lbs

SPEED: (Max Surface) 4 kts
(Max Current) NA
STRUCTURE: Rectangular-shaped open Al framework encloses and supports all components. Synthetic foam blocks affixed to top of framework are adjusted for slightly positive buoyancy.

PROPULSION: Three 10 hp, 440 VAC electric motors power three propellers, all capable of independent operation. Two provide forward-reverse thrust, one provides vertical motion.

INSTRUMENTATION: Two CCTV cameras, 35mm still camera, lights, altimeter, depthometer, mag compass, active and passive CTFM sonar, hydraulically powered 5-function manipulator and tool assembly.

POWER REQ: 400VAC, 120VAC, 3Ø, 50KW. All power supplied by portable 60KW diesel generator.

SHIPBOARD COMPONENTS: Portable van with remote console, generator, and conversion equipment, launch/retrieval system.

SUPPORT VESSEL REQ: YFNX-30 serves as support craft for local operations. YFNX-30 has 110' length, 34' beam, 5' draft, 6.5' freeboard, and a speed of 5.5 kts.

CREW: 7, 10 in emergency mission
TOTAL SHIPPING VOL: 4,500 cu ft plus handling crane is necessary

TOTAL SHIPPING WEIGHT: 26 tons plus crane

BUILDER: Naval Ocean System Center, San Diego, CA

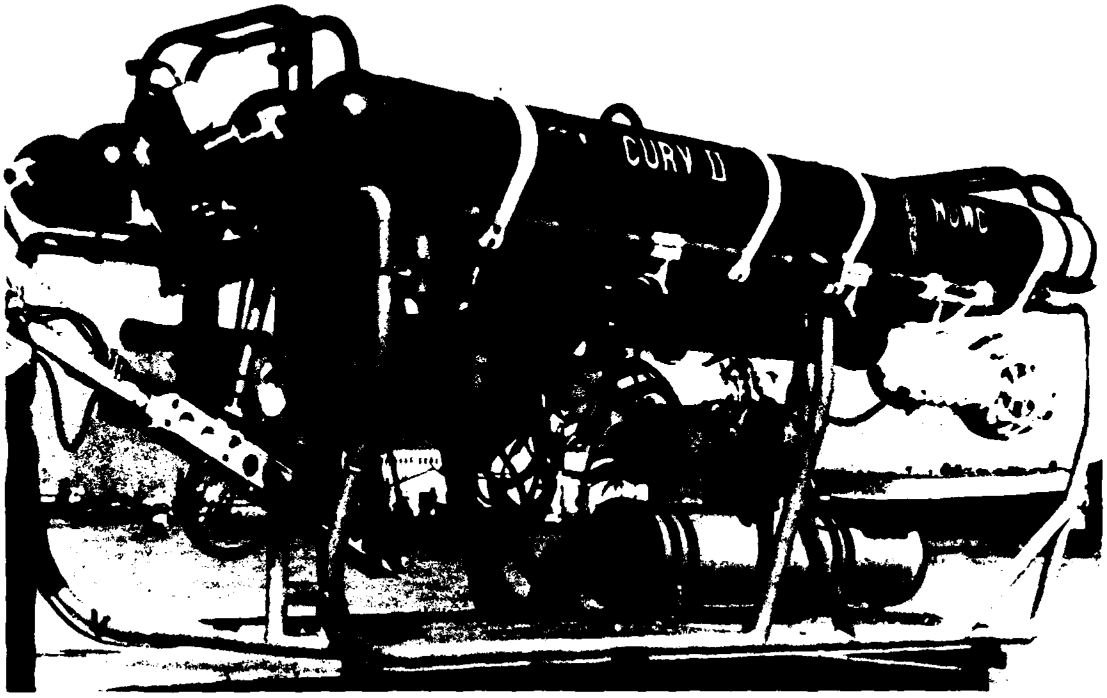


FIGURE B.4 - CURV II
Courtesy of: Naval Ocean Systems Center

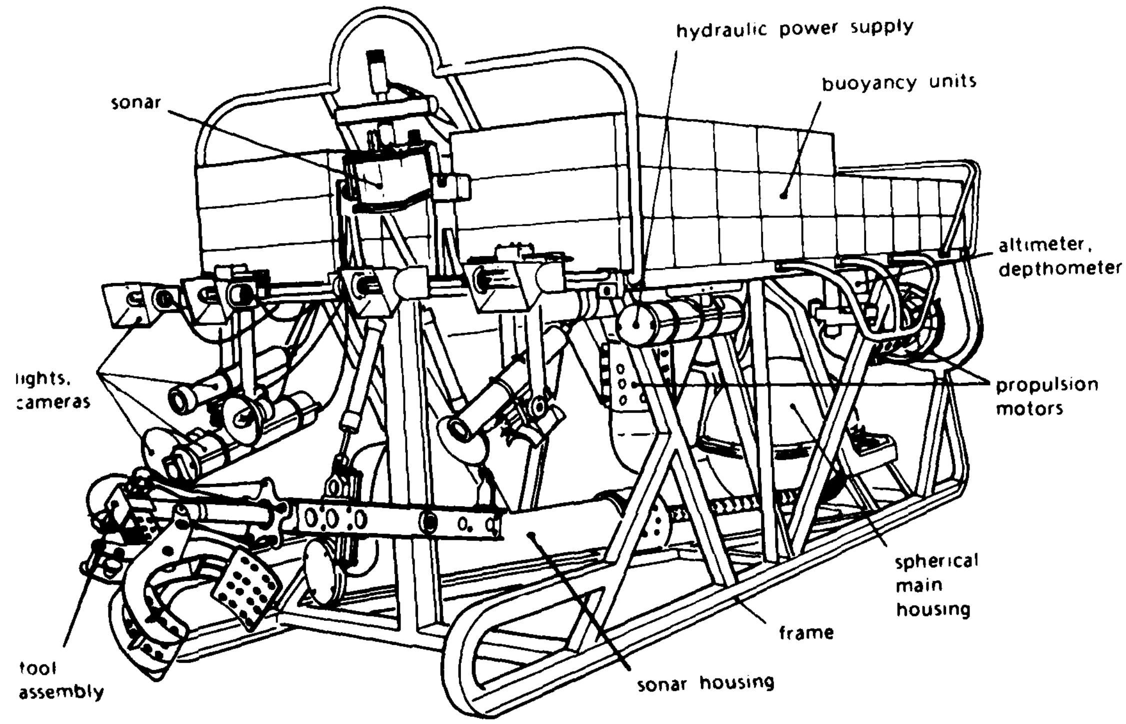


FIGURE B.5 - CURV III
Courtesy of: Naval Ocean Systems Center

CUTLET

DEPTH: 1,148'
DIMENSIONS (LxWxH): 180" x 67" x 83"
WEIGHT: 2,536 lbs

SPEED: (Max Surface) NA
(Max Current) NA
STRUCTURE: Open metal framework with ring-stiffened tanks for buoyancy.

PROPULSION: Three 10 hp, reversible, electric thrusters (2 long, 1 vert). Maneuvering accomplished by independent control of thrusters.

INSTRUMENTATION: Two CCTV cameras on p&t units, mag compass, depthometer, altimeter, torpedo locator, obstacle avoidance sonar, transponder, hydraulical manipulator with circular-type (torpedo grasping) claw.

POWER REQ: 440V, 60Hz, 3Ø.

SHIPBOARD COMPONENTS: Power supply, cable tray, winch.

SUPPORT VESSEL REQ: Crane rated for vehicle weight, deck space: 12.8' x 9.8' x 8.9' for control van.

CREW: NA
TOTAL SHIPPING VOL: NA

TOTAL SHIPPING WEIGHT: NA

BUILDER: Admiralty Underwater Weapons Establishment, Portland, Dorset DT5 2JS, England

ERIC 1
(Engin de Recherche et d'Intervention a Cable)

DEPTH: 1600'
DIMENSIONS (LxWxH): 157" x 78" x 78"
WEIGHT: 6,160 lbs

SPEED: (Max Surface) NA
(Max Current) 5 kts
STRUCTURE: Metallic open framework encloses and supports all components.

PROPULSION: Three 10KW continuously variable speed motors driving 27" propellers (2 lat, 1 vert). Maneuvering by differential control of thrusters.

INSTRUMENTATION: CCTV on p&t, pressure gauge, altimeter, gyro, scanning sonar, manipulator with 5 DOF.

POWER REQ: 90KVA, 60Hz, 3Ø; 50KW diesel electric generator supplies all power.

SHIPBOARD COMPONENTS: NA

SUPPORT VESSEL REQ: Launch/retrieval crane with 6,750 lb capacity and 23' reach.

CREW: 3
TOTAL SHIPPING VOL: NA

TOTAL SHIPPING WEIGHT: NA

BUILDER: Built in 1971 by Centre d'Etudes et de Recherches Techniques Sous-Marines (CERTSM), 83800 Toulon-Naval, France
COMMENTS: Designed for TV survey work, research, and object retrieval. Payload capacity up to 112 lbs. Objects retrieved up to 0.9' x 0.9' x 0.9'.

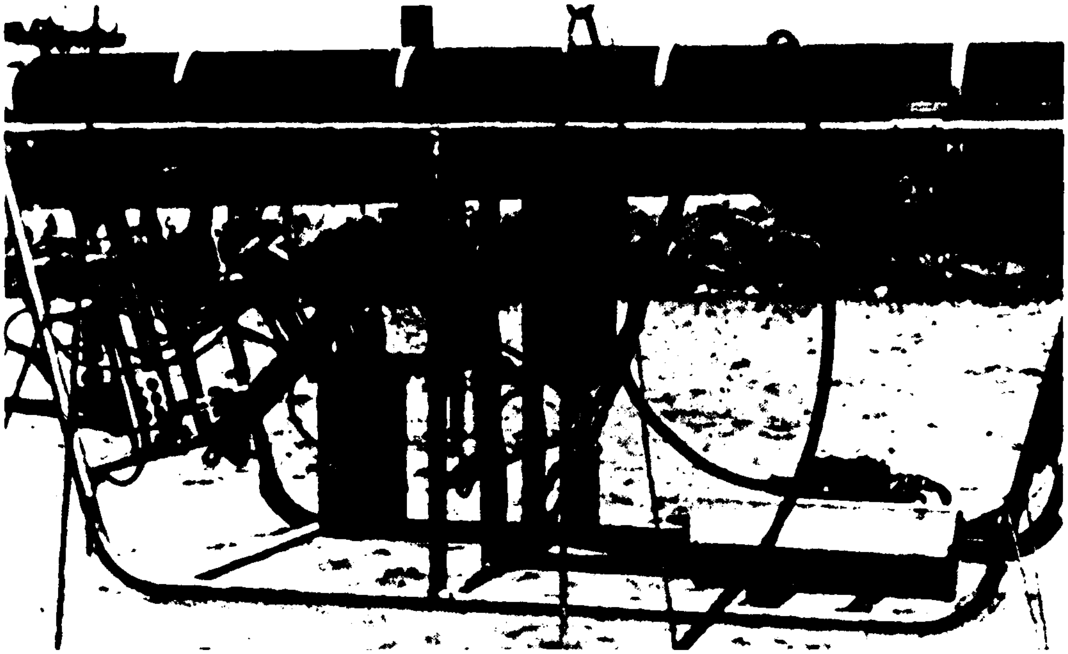


FIGURE B.6 - CUTLET
Courtesy of: Admiralty Underwater Weapons Establishment

FIGURE B.7 - ERIC I
Courtesy of: Centre d'Etudes et de Recherches Techniques Sous-Marines

ERIC 11

DEPTH: 19,685'
DIMENSIONS (LxWxH): Vehicle: 197" x 118" x 71"; Clump: 252" x 146" x 102"
WEIGHT: Fish: 5.5 tons; Clump: 2.75 to 4.4 tons

SPEED: (Max Surface) NA
(Max Current) NA
STRUCTURE: Fish has fiberglass fairing with teardrop shape which encloses all components. A clump, Pagode, houses Eric during launch/retrieval and maintains taut main umbilical while Eric operates on 948 ft tether.

PROPULSION: Six thrusters providing six degrees of maneuvering freedom.

INSTRUMENTATION: Head following CCTV, cine camera, scanning sonar, gyrocompass and vertical gyro, echo sounder, depthometer, two manipulators with force feedback.

POWER REQ: 115V, 1Ø, 100KW max, supplied by diesel generator.

SHIPBOARD COMPONENTS: Control console in portable van, cable and fish-handling equipment, acoustic navigation equipment.

SUPPORT VESSEL REQ: Launch/retrieval system rated for vehicle and clump weight, dynamic positioning capability.

CREW: 2
TOTAL SHIPPING VOL: Approx 7,838 cu ft plus control van and diesel generator

TOTAL SHIPPING WEIGHT: 52.4 tons plus control van and diesel generator

BUILDER: CERTSM, 83800 Toulon-Naval, France

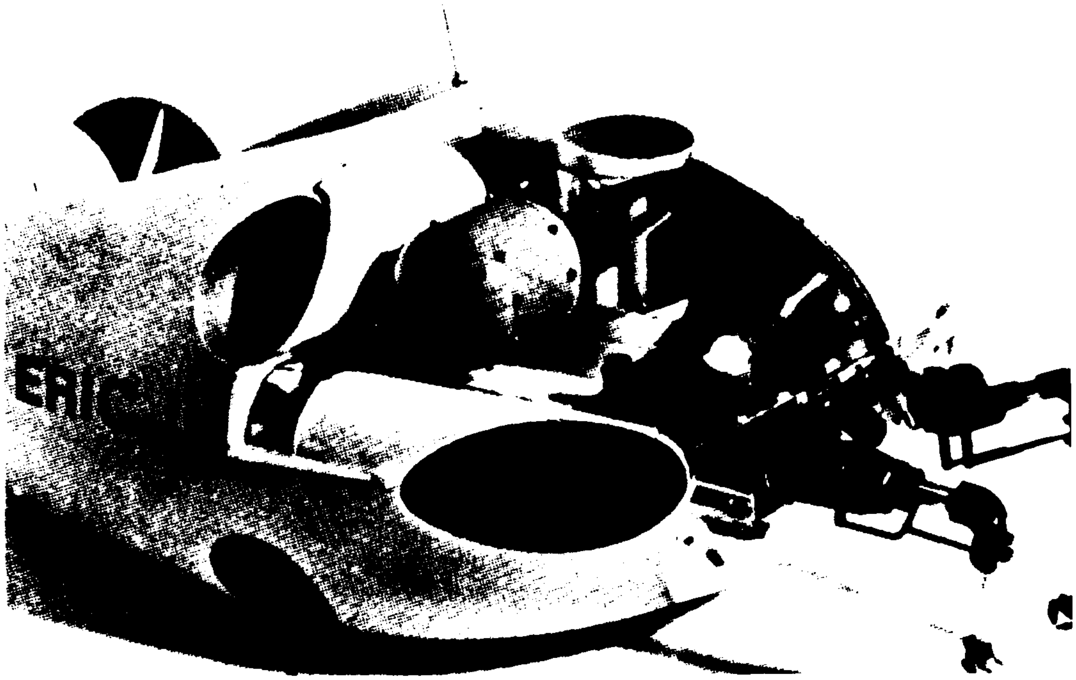


FIGURE B.8a - ERIC II
Courtesy of: CERTSM

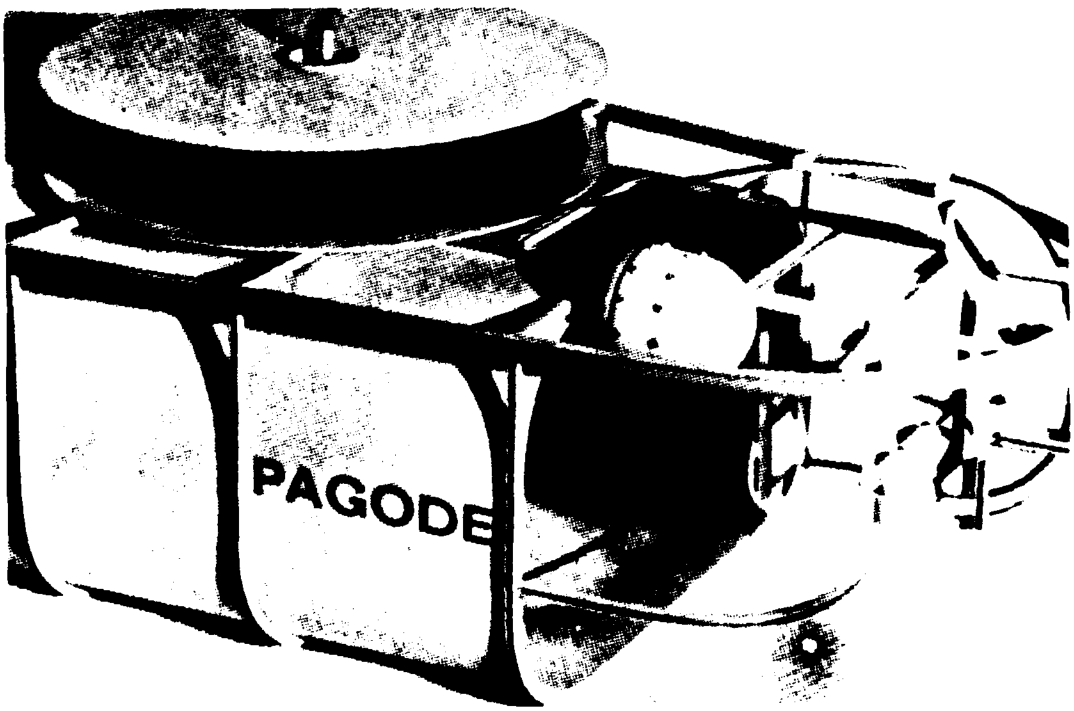


FIGURE B.8b - PAGODE LAUNCHING DEVICE FOR ERIC II
Courtesy of: CERTSM

ERIC 10

DEPTH: 1,640'
DIMENSIONS (LxWxH): 157" x 79" x 79"
WEIGHT: 3.1 tons

SPEED: (Max Surface) 4 kts
(Max Current) 2 kts
STRUCTURE: Rectangular shape with open Al framework which supports and protects all components.

PROPULSION: Three reversible electric thrusters, with continuously variable speed control, capable of independent operation. Each provides up to 450 lbs thrust.

INSTRUMENTATION: B&W CCTV camera on p&t, still camera, six 400W quartz iodide lights, depthometer, CTFM sonar, inclinometer, echo sounder, mag compass, two surface flashing lights, hydraulically powered manipulator with 5 DOF, and parallel jaws-type claw.

POWER REQ: 440V, 60Hz, 3Ø, 60KVA provided by diesel generator.

SHIPBOARD COMPONENTS: Portable van with control console, cable winch, launch/retrieval crane, diesel generator.

SUPPORT VESSEL REQ: Deck space for van and components storage, capacity for a handling crane weighing 14.4 tons, control van (3.9 tons), and vehicle (3.1 tons).

CREW: 5
TOTAL SHIPPING VOL: 1,588 cu ft

TOTAL SHIPPING WEIGHT: 11 tons

BUILDER: CERTSM, 83800 Toulon-Naval, France

COMMENTS: Commercial version of ERIC 1, design for identifying objects on the seabed via TV and photography, wreck surveying, and carrying out minor lifting or mechanical work tasks.

EV-1

DEPTH: 1,500'
DIMENSIONS (LxWxH): 52" x 32" x 24"
WEIGHT: Vehicle: 250 lbs; launcher (if used): NA

SPEED: (Max Surface) 2 kts
(Max Current) 0.5 kts @ max depth
STRUCTURE: Welded tubular steel frame supports and encloses all components. Neutral buoyancy achieved by two syntactic foam cylinders strapped to frame. Up to 40 lbs additional buoyancy may be provided for additional payload requirements.

PROPULSION: Three fixed, reversible hydraulic thrusters (one stern-mounted, one lat, one vert).

INSTRUMENTATION: Fixed CCTV camera, two 250W tungsten halogen lights, mag compass, depthometer, leak detector, and hydraulic system temp sensor. Hydraulic tool (arm) extends 21 inches in front of vehicle, with limited wrist rotation and three-finger claw capable of grabbing 6-inch diameter object.

POWER REQ: 220 to 440VAC, 60Hz, 3Ø, 5KW max.

SHIPBOARD COMPONENTS: Control console, power distribution package, winch.

SUPPORT VESSEL REQ: Enclosed area for control console, generator.

CREW: 2 to 3
TOTAL SHIPPING VOL: 52.5 cu ft

TOTAL SHIPPING WEIGHT: 10,251 lbs

BUILDER: Ocean Systems Division, Kraft Tank Co., Kansas City, MO

COMMENTS: To date, the manufacturer has completed a single prototype vehicle.

MANTA 1.5

DEPTH: 4,921'
DIMENSIONS (LxWxH): 78" x 62" x 40"
WEIGHT: 2,200 lbs

SPEED: (Max Surface) 3 kts
(Max Current) NA
STRUCTURE: Open metal framework construction.

PROPULSION: Four fixed, reversible 1.5 hp thrusters.

INSTRUMENTATION: CCTV, three 500W lights, side-scan sonar, manipulator with 5 DOF, with 22 lbs lifting capacity, and various types of claws.

POWER REQ: 380V, 50Hz, 3Ø

SHIPBOARD COMPONENTS: Control console, launch/retrieval system.

SUPPORT VESSEL REQ: NA

CREW: 3
TOTAL SHIPPING VOL: 706 cu ft

TOTAL SHIPPING WEIGHT: 4 tons

BUILDER: Academy of Sciences USSR, Moscow

MURS-100
(Mitsui Unmanned Remotely Controlled Submersible)

DEPTH: 328' (emergency dive to 492')
DIMENSIONS (LxWxH): 100" x 74" x 49"
WEIGHT: 1,984

SPEED: (Max Surface) 2 kts
(Max Current) NA
STRUCTURE: An acrylic plastic, hydrodynamically shaped shell encloses a pressure-resistant inner shell consisting of a transparent acrylic plastic hemisphere jointed to a steel sphere. Inner shell contains CCTV camera and controls and thruster control units. Outer shell is supported by an open metal framework with skids.

PROPULSION: Two oil-filled reversible electric thrusters, with continuously variable speed control, provide up to 132 lb thrust each; mounted amidships port and starboard. Thrusters can be rotated $\pm 90^{\circ}$.

INSTRUMENTATION: CCTV camera (color) with mirror p&t unit, eight 500W halogen lights, mag compass, inclinometer, depthometer, speedometer, transponder, electro-hydraulically powered system (slave arm) having six functions and an 88 lb lifting capacity.

POWER REQ: 440VAC, 60Hz, 3Ø, 30KVA supplied from ship service or diesel generator.

SHIPBOARD COMPONENTS: Control console, power panel, cable winch.

SUPPORT VESSEL REQ: Launch/retrieval crane rated at 1 ton with 6' reach. Deck space: 20' x 20' plus crane and generator (if necessary) space.

CREW: 3
TOTAL SHIPPING VOL: Approx 989 cu ft

TOTAL SHIPPING WEIGHT: Approx 5 tons

BUILDER: Built in 1975 by Mitsui Ocean Development and Engineering Co. (MODEC), Ltd., Tokyo, Japan.

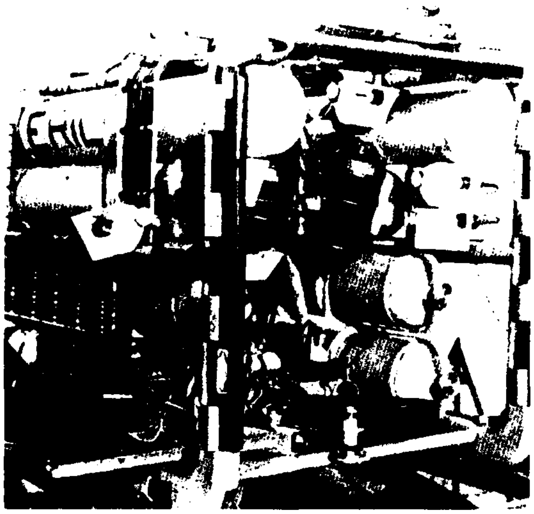


FIGURE B.9 - ERIC 10
Courtesy of: NOAA

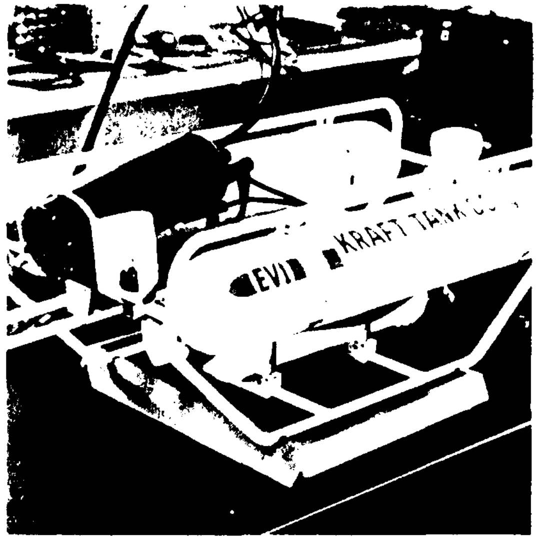


FIGURE B.10 - EV-1
Courtesy of: Kraft Tank Company

FIGURE B.11 - MURS 100
Courtesy of: MODEC

MURS-300

DEPTH: 984'
DIMENSIONS (LxWxH): 105" x 75" x 64"
WEIGHT: 5,291 lbs

SPEED: (Max Surface) NA
(Max Current) 3.0 kts
STRUCTURE: Rectangular-shaped open metal framework encloses and supports all components. A syntactic foam float is attached to top of framework.

PROPULSION: Four hydraulic thrusters (2 long, 1 vert, 1 lat) driven by a 7.5 hp hydraulic pump.

INSTRUMENTATION: Two CCTV cameras (1 color, 1 low light B&W) on p&t unit, 35mm still camera with strobe, four 250W lights, two 500W lights, echo sounder, depthometer, gyro, trim gage, CTFM sonar, cable cutter. Two manipulators: one bilateral (master/slave) with 7 DOF, 44 lb lift capacity; one with 5 DOF and 88 lb lift capacity.

POWER REQ: 22VAC, 60Hz, 3Ø, 60KVA.

SHIPBOARD COMPONENTS: Control console and power panel in portable van, cable winch.

SUPPORT VESSEL REQ: Deck space for van and cable winch (755 cu ft), power supply, and launch/retrieval system.

CREW: 2 plus maintenance crew
TOTAL SHIPPING VOL: Approx 2,553 cu ft

TOTAL SHIPPING WEIGHT: NA

BUILDER: Mitsui Ocean Development and Engineering Co., Ltd., Tokyo, Japan

ORCA 1
(Oceaneering Remote-Controlled Arms)

DEPTH: 2,300'
DIMENSIONS (LxWxH): 11.5' x 6.6' x 6.6'
WEIGHT: 6,000 lbs

SPEED: (Max Surface) NA
(Max Current) NA
STRUCTURE: Rectangular, open metal framework encloses and supports all components. Syntactic foam blocks mounted on top of frame.

PROPULSION: Seven 6KW hydraulic thrusters provide maneuvering in all translational and rotational directions.

INSTRUMENTATION: Two CCTV: one fixed camera with wide-angle lens, one p&t mounted with zoom lens, four mercury vapor lights, two halogen lights, stereo still cameras. Three manipulators: one master-slave force feedback unit (GE Arms) with lift capacity of 65-100 lbs, grip force of 247 lbs, reach of 5'6"; two grabber manipulators capable of lifting 175 lb at full reach (6'3"); tool rack, echo sounder, two directional hydrophones, transponder, gyro, depth meter.

POWER REQ: 440VAC, 60Hz; 380V, 50Hz.

SHIPBOARD COMPONENTS: Control console and computer, transformer, launch/retrieval system.

SUPPORT VESSEL REQ: Deck space: 538 to 861 sq ft.

CREW: NA
TOTAL SHIPPING VOL: NA

TOTAL SHIPPING WEIGHT: 12 tons plus launch/retrieval device

BUILDER: Saab-Scania, Aerospace Division, Linkoping, Sweden

PHOCAS II
(Photo Optical Cable-Controlled Submersible)

DEPTH: 984'
DIMENSIONS (LxWxH): 79" x 32" x 32"
WEIGHT: 500 lbs

SPEED: (Max Surface) 1.5 kts
(Max Current) NA

STRUCTURE: Rectangular-shaped open, Al framework encloses and supports all components. Fourteen 8" diameter Nokulon floats provide buoyancy. Near bottom altitude is controlled by a drag chain and pneumatically controlled variable ballast tank.

PROPULSION: Two 0.5 hp electric thrusters mounted on stern give forward/reverse and yaw motion. Vertical motion controlled by variable ballast and drag chain.

INSTRUMENTATION: CCTV and 35mm still camera on tilt unit, 400W thallium iodide light, 160WS strobe, mag compass, depthometer, echo sounder, transponder interrogator. Manipulator with 3 DOF designed for collecting bottom samples.

POWER REQ: 380/220VAC, 50Hz, 3 or 1Ø, 5KW.

SHIPBOARD COMPONENTS: Control console, generator, cable drum and winch.

SUPPORT VESSEL REQ: Air supply (140 cu ft @ 3,000 psi), cabin space for control console of 7.6 cu ft, launch/retrieval system.

CREW: 3
TOTAL SHIPPING VOL: NA

TOTAL SHIPPING WEIGHT: NA

BUILDER: Geologian Tutkimuslaitos, Otaniemi, Finland

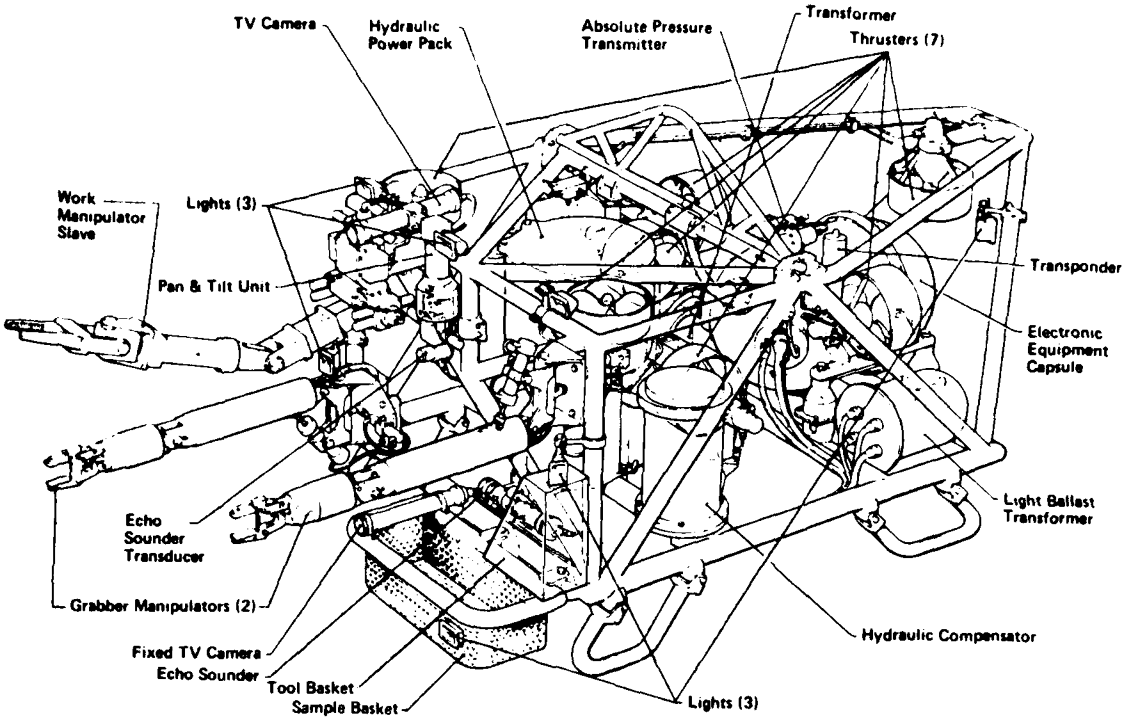


FIGURE B.12 - ORCA I
Courtesy of: Saab-Scania AB

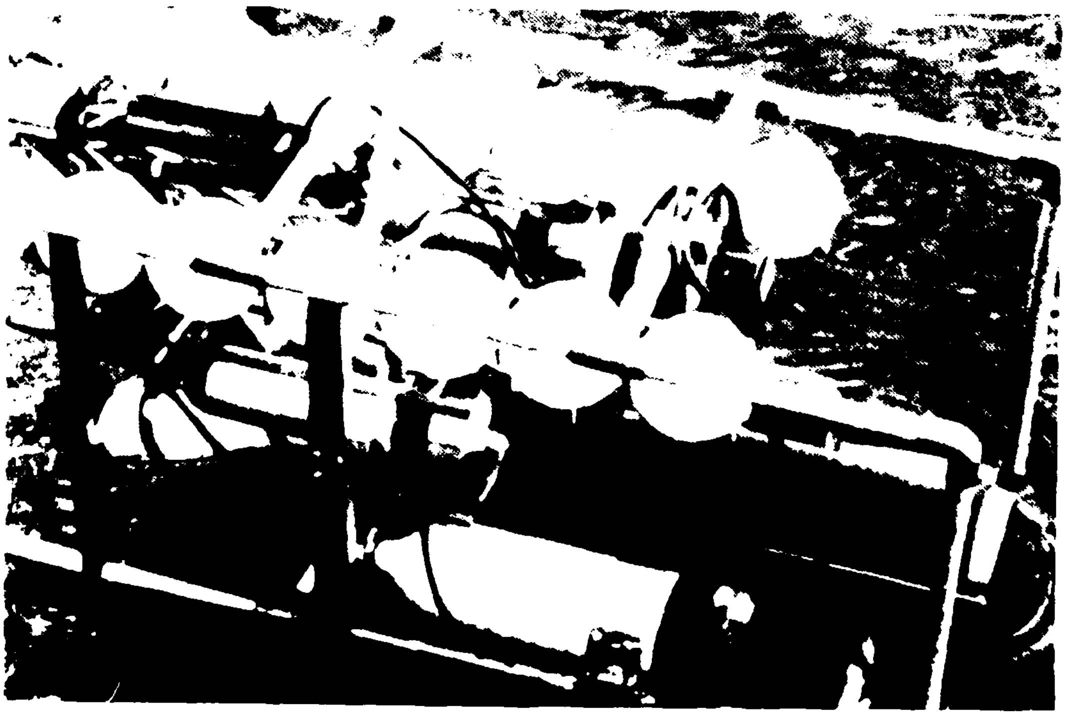


FIGURE B.13 - PHOCAS II
Courtesy of: Geologinen Tutkimuslaitos

RCV-150

DEPTH: 6,600'
DIMENSIONS (LxWxH): 52" x 47" x 43"
WEIGHT: Vehicle: 1,000 ± 50 lbs depending on equipment options; launcher: 2,500 lbs.
SPEED: (Max Surface) 2.0-2.5 kts
(Max Current) 1.5-2.0 kts @ max depth
STRUCTURE: Glass-reinforced framework covered with syntactic foam to form a nearly cubic structure which encloses all components except thrusters and manipulator.

PROPULSION: Four reversible thrusters (2 long, 2 vert/transverse) powered by 15 hp electric/hydraulic pump; servocontrol system for auto depth function.

INSTRUMENTATION: CCTV (low light, B&W) with tilt lens, four 250W lamps, depthometer, heading sensor, inclinometer, speedometer, leak detector, hydraulic fluid temp sensor. Manipulator with 4 DOF, lift capacity 25 lbs at full extension. Optional tools include grabber arm, cable cutter, pinger dropper, etc.

POWER REQ: 440 or 220VAC, 50/60 Hz, 3Ø

SHIPBOARD COMPONENTS: Control console, remote consolette, winch, A-frame, hydraulic power supply, diesel generator (if necessary).

SUPPORT VESSEL REQ: Cabin space for control console, deck space for vehicle and handling equipment, stationkeeping ability.

CREW: 3
TOTAL SHIPPING VOL: 252 cu ft plus deployment unit, winch and cable, and handing equipment.
TOTAL SHIPPING WEIGHT: Approx 26,000 lbs

BUILDER: Hydro Products, Box 2528, San Diego, CA 92112

COMMENTS: Vehicle is deployed in underwater launcher unit (6.2' x 6' diameter, 2,500 lbs) and conducts excursions on neutrally buoyant, 600' tether cable.

FIGURE B.14a - RCV 150
Courtesy of: Hydro Products

FIGURE B.14b - RCV 150 SYSTEM
Courtesy of: Hydro Products

RECON II

DEPTH: 1,500'
DIMENSIONS (LxWxH): Vehicle: 42" x 38" x 32"; launcher: 36" x 30" x 36"
WEIGHT: Vehicle: 650 lbs; launcher: 1,500 lbs.

SPEED: (Max Surface) 3 kts
(Max Current) 2 kts
STRUCTURE: Open, tubular metal framework which encloses and protects all components. Neutral buoyancy achieved by syntactic foam mounted on top of framework.

PROPULSION: Four fixed, reversible, hydraulic-powered thrusters (2 long, 1 lat, 1 vert) with continuously variable speed control. A 5 hp electric motor drives the hydraulic pump.

INSTRUMENTATION: CCTV on p&t unit, two 250W incandescent lamps, mag compass, depthometer, current meter, altimeter. Hydraulic manipulator with 3 DOF and cable cutter. Transponder and a variety of other instrumentation is optional.

POWER REQ: 440 or 220VAC, 60 Hz, 3Ø

SHIPBOARD COMPONENTS: Control console and CCTV monitor and recorder, transformer, launch/retrieval system, cable winch.

SUPPORT VESSEL REQ: 1.5 ton winch, 2,000' of 8,000 lb wire rope, power supply.

CREW: 3
TOTAL SHIPPING VOL: 65.8 cu ft plus umbilical and reel

TOTAL SHIPPING WEIGHT: 2,100 lbs plus control console, umbilical and reel, transformer, and launch/retrieval system.
BUILDER: Perry Oceanographics, Inc., 100 E. 17th St., Riviera Beach, FL 33404

COMMENTS: Not currently a production model. Updated to RECON III.

RECON V

DEPTH: 1,200'
DIMENSIONS (LxWxH): 75" x 36" x 30"
WEIGHT: 850 lb max (fully outfitted)

SPEED: (Max Surface) 2.5 kts
(Max Current) NA

STRUCTURE: Rectangular-shaped tubular Al framework which encloses and protects all components. Slight positive buoyancy provided by syntactic foam block mounted on top of framework.

PROPULSION: Five reversible, hydraulic thrusters, 75 lbs thrust each (2 long, 2 vert, 1 lat).

INSTRUMENTATION: CCTV with two 250W tungsten iodide lights on p&t unit, gyro, depthometer, autohover and heading control, cable twist and slack indicator. Hydraulic manipulator with 4 DOF, can grasp objects up to 4" in diameter. Position system (Honeywell RS-7) and scanning sonar are optional.

POWER REQ: 208/240/480VAC, 60 Hz, 3Ø, 100KVA

SHIPBOARD COMPONENTS: Control console, portable consolette, optional control van, transformer (3' x 2.5' x 1', 150 lbs), umbilical winch, launch/retrieval system. Optional handling system including slip-ring winch, 12' x 7' x 7.5', 5000 lbs, may be provided by Perry.

SUPPORT VESSEL REQ: Launch/retrieval system, sufficient control for live boat operations (twin screws, bow thruster).

CREW: 3
TOTAL SHIPPING VOL: 136 cu ft

TOTAL SHIPPING WEIGHT: 2,050 lbs

BUILDER: Perry Oceanographics, Inc., 100 E. 17th St., Riviera Beach, FL 33404

COMMENTS: Payload with standard configuration is 25 lbs, 75 lbs with optional buoyancy package.

RECON VI

DEPTH: 1,500'; optional 3000'
DIMENSIONS (LxWxH): 126" x 60" x 60"
WEIGHT: 3900 lbs

SPEED: (Max Surface) NA
(Max Current) NA
STRUCTURE: Open, metallic framework encloses and protects all components. Syntactic foam provides buoyancy. Payload capacity of 220 lbs. Optional payload capacity available.

PROPULSION: Four reversible electric thrusters (2 long, 1 vert, 1 lat), 220 lbs thrust each. Two additional longitudinal, and one additional vertical thruster are optional.

INSTRUMENTATION: Low light level CCTV camera on p&t, two 200W mercury vapor lights, two 500W incandescent lights, directional gyro, navigational sonar, depthometer, one four-function grabber, one six-function manipulator. Options include NDT equipment, pipe tracking instruments, hydraulic tools.

POWER REQ: 480VAC, 60 Hz, 3Ø, 50KVA

SHIPBOARD COMPONENTS: Control console, umbilical winch, and storage drum.

SUPPORT VESSEL REQ: Launch/retrieval device, deck space for shipboard components and vehicle.

CREW: 4
TOTAL SHIPPING VOL: NA

TOTAL SHIPPING WEIGHT: NA

BUILDER: Perry Oceanographics, Inc., 100 E. 17th St., Riviera Beach, FL 33404

COMMENTS: Commercial version of this vehicle has yet to be constructed.

RUWS
(Remote Unmanned Work System)

DEPTH: 20,000'
DIMENSIONS (LxWxH): Vehicle: 132" x 57" x 60"; PCT: 115" x 60" x 72"
WEIGHT: Vehicle: 7,000 lbs; PCT: 5,500 ± 300 lbs

SPEED: (Max Surface) 1 kt
(Max Current) NA

STRUCTURE: Rectangular-shaped angular Al framework which encloses all components. Syntactic foam blocks mounted atop framework provide buoyancy. Primary Cable Termination (PCT): rectangular-shaped angular Al framework which encloses vehicle tether (850') winch.

PROPULSION: Vehicle: Five reversible, continuously variable hydraulic thrusters (2 long, 2 lat, 1 vert) driven by 15 hp hydraulic pump. PCT has four thrusters for stationkeeping.

INSTRUMENTATION: Stereo CCTV (head coupled or manual control of p&t unit), lights, mag compass, 70mm still camera, CTFM sonar, two directional hydrophones, altimeter. Two manipulators: one 7 DOF position controlled, one 4 DOF rate control grabber arm.

POWER REQ: 60KW diesel-electric generators supply all power.

SHIPBOARD COMPONENTS: Control/navigation van, maintenance van, near-surface navigation transducer with handling system, generators, motion-compensated launch/retrieval crane.

SUPPORT VESSEL REQ: Deck space of 700 sq ft for all components. System designed for deployment from specific ships of opportunity.

CREW: NA
TOTAL SHIPPING VOL: Air-transportable in three C-141As or one C-5A aircraft

TOTAL SHIPPING WEIGHT: 82 tons

BUILDER: Naval Undersea Center, Kailua, Hawaii

COMMENTS: This system designed to perform a variety of work tasks at depths covering 98 percent of ocean floor. System is deployed with PCT which serves as a line weight (3500 lbs negatively bouyant) to aid in stationkeeping and to limit dynamic forces that might otherwise be transmitted to vehicle. It also serves as signal distribution center between primary cable and buoyant vehicle tether.

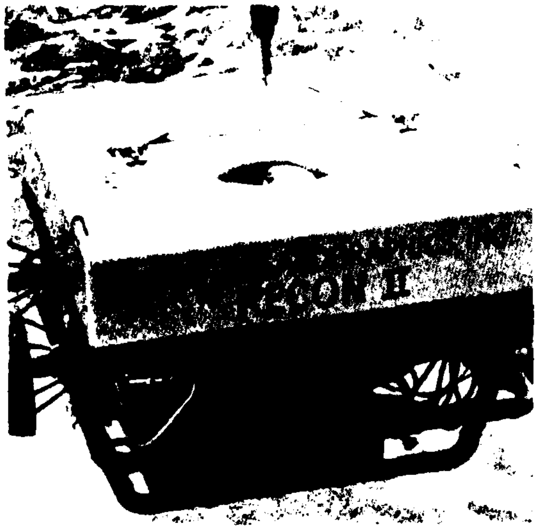


FIGURE B.15 - RECON II
Courtesy of: Perry Ocean Group

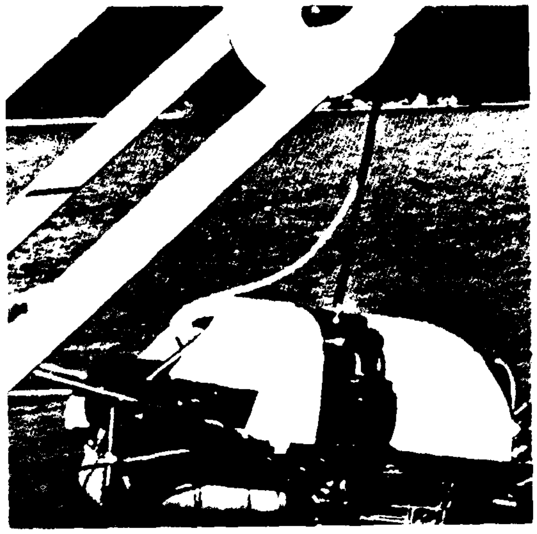


FIGURE B.16 - RECON V
Courtesy of: Perry Ocean Group

FIGURE B.17 - RUWS
Courtesy of: U.S. Navy

SCARAB
(Submersible Craft Assisting Repair and Burial)

DEPTH: 6,000'
DIMENSIONS (LxWxH): 132" x 72" x 60"
WEIGHT: Vehicle: 5,000 lbs; complete system: 75,000

SPEED: (Max Surface) 3 kts
(Max Current) 0.5 kts @ max depth
STRUCTURE: Open tubular framework encloses and supports all components. Fifty lbs buoyancy provided by cylindrical flotation tanks at top of vehicle.

PROPULSION: Six AC, 2000V, 3Ø, 5 hp electric thrusters (2 port, 2 starbd, 2 vert) providing about 1,800 lbs total thrust. One rotatable 5 hp, lateral thruster with 300 lbs thrust.

INSTRUMENTATION: Two low light CCTV (one with zoom) on p&t unit, one 35mm still camera, lights, bottom contour following sensors, altimeters, depthometer, magnetometer (cable locator), search sonar, 35 hp motor and pump with dredge and jet nozzles for cable burial, unburial. Two hydraulic manipulators with 5 DOF, equipped with various cable-gripping and cutting devices.

POWER REQ: 480VAC, 60Hz, 3Ø, 150 KW provided by diesel generator, one spare generator included with system.

SHIPBOARD COMPONENTS: Power distribution unit, control console, navigation plotter, diesel generators, vehicle locator unit, motion-compensated handling unit with cable storage reel.

SUPPORT VESSEL REQ: Deck space for shipboard components and vehicle.

CREW: 3 plus 2 deck hands
TOTAL SHIPPING VOL: All components will fit in eight standard A-2 freight containers, 560 cu ft each.
TOTAL SHIPPING WEIGHT: 94,000 lbs

BUILDER: Ametek, Straza Division, 790 Freefield Drive, PO Box 666, El Cajon, CA 92022
COMMENTS: Designed under contract primarily for use by telephone companies. Vehicle is capable of locating, unburying, attaching grippers and lift line, cutting, recovering, and reburying cables down to 6,000 feet. System is designed to be completely independent of ship crew.

SCORPIO
(Submersible Craft for Ocean Repair, Positioning, Inspection, and Observation)

DEPTH: 3,000'
DIMENSIONS (LxWxH): 88" x 48" x 64"
WEIGHT: 1,500 lbs

SPEED: (Max Surface) 3 kts
(Max Current) 1 kt against 1 kt current @ max depth
STRUCTURE: Rectangular open tubular Al framework which encloses all components. Buoyancy provided by two pressure-resistant flotation tanks which also house electronic components.

PROPULSION: Four proportionally controlled, hydraulic thrusters (2 long, 1 lat, 1 vert) giving 250 lbs thrust each.

INSTRUMENTATION: CCTV on p&t unit, CTFM sonar (Ametek Model 250) gives 360° search and obstacle avoidance capabilities. Sonar also tilts down for bottom search and survey. Auto depth and heading control, cable twist sensor, acoustic pinger and strobe flasher for emergency recovery assist. Hydraulic manipulator with 5 DOF, 200 lb lift capability. Optional equipment: hydraulic 3 DOF grabber arm, altimeter, sub-bottom profiling sonar, side-scan sonar, magnetometer, etc.

POWER REQ: 440 to 480VAC, 60Hz, 3Ø, 50KW.

SHIPBOARD COMPONENTS: Control console with portable control box, power distribution unit, winch and cable reel. Power generator and launch/retrieval frame are optional.

SUPPORT VESSEL REQ: Cabin space for control console and operators; handling system, and appropriate power are optional (can be supplied with system). Vessel should have good stationkeeping abilities for live boat operations. Deck space: 20' x 12' for vehicle, winch, and flotation hose.
CREW: 3-4
TOTAL SHIPPING VOL: Approx 600 cu ft

TOTAL SHIPPING WEIGHT: 10,000 lbs max

BUILDER: Ametek, Straza Division, 790 Freefield Drive, PO Box 666, El Cajon, CA 92022
COMMENTS: SCORPIO is designed specifically for offshore requirements. Tasks which may be performed using this vehicle include pipeline inspection, site survey, deep object placement and recovery.

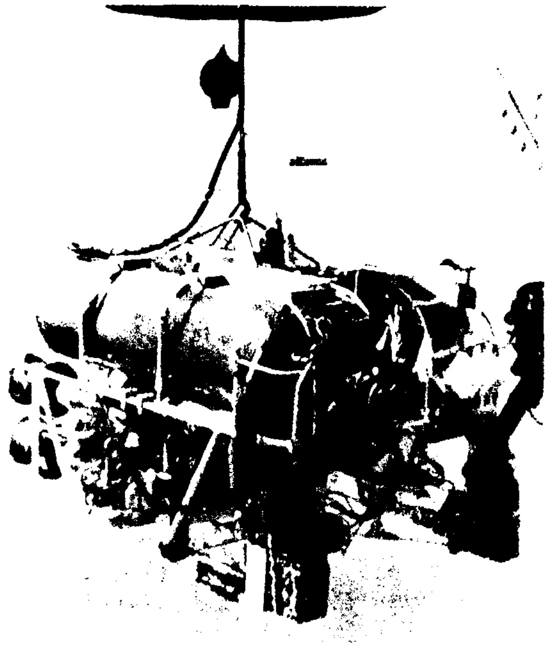


FIGURE B.18 - SCARAB
Courtesy of: Ametek Straza Division

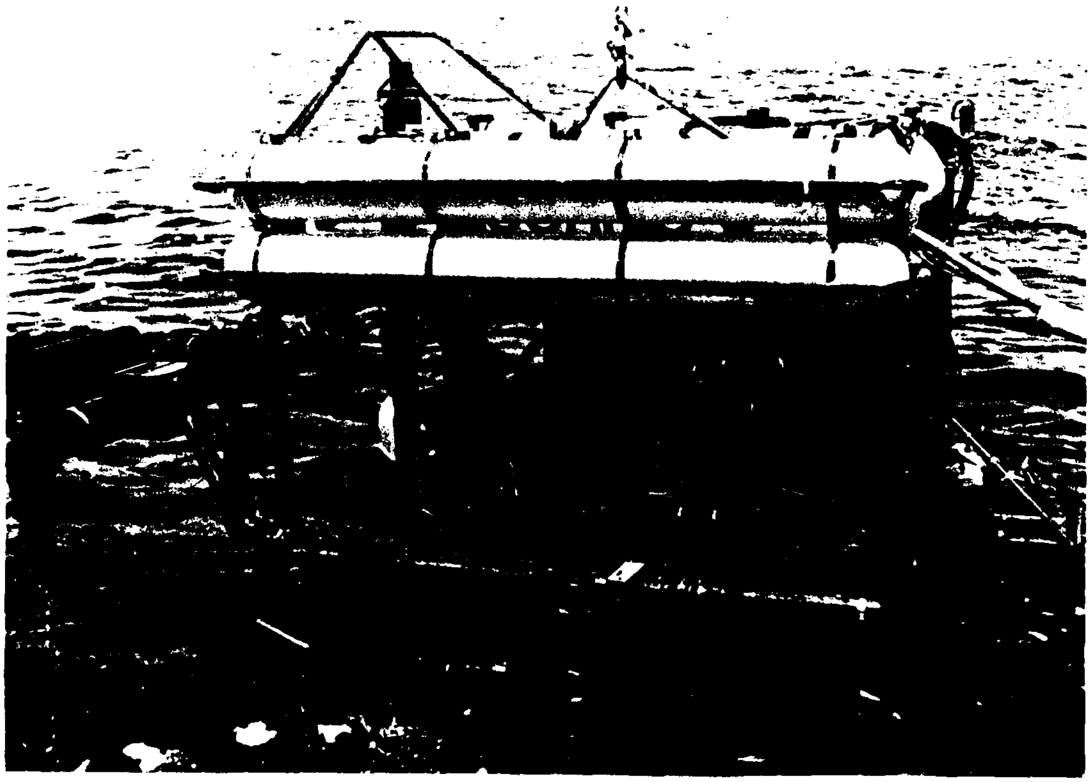


FIGURE B.19 - SCORPIO
Courtesy of: Ametek Straza Division

SMIT SUB-1000

DEPTH: 3,280'
DIMENSIONS (LxWxH): 86" x 86" x 62"
WEIGHT: Approx 1,550 lbs

SPEED: (Max Surface) NA
(Max Current) Approx 1.5 kts of max depth
STRUCTURE: Circular-shaped open tubular Al framework encloses and supports all components. Syntactic foam at top of frame provides slight positive buoyancy.

PROPULSION: Five thrusters (2 long, 2 lat with 660 lbs thrust each, 1 vert with 275 lbs thrust), vertical thruster in servocontrol loop for auto-depth control.

INSTRUMENTATION: Two CCTV cameras (one SIT with 140° wide angle lens, one mounted on p&t unit), two 250W quartz iodide lights, 35mm still camera with 1,000 ws strobe, altimeter, sub-bottom profiler, CTFM sonar, side-scan sonar, mag compass, depthometer. Two manipulators. Honeywell RS-7 navigation system is optional.

POWER REQ: 380/440VAC, 50/60Hz, 3Ø, 125KVA max.

SHIPBOARD COMPONENTS: Control console, launch/retrieval system, power supply.

SUPPORT VESSEL REQ: Deck space of 600 sq ft minimum.

CREW: NA
TOTAL SHIPPING VOL: Approx 4,573 cu ft

TOTAL SHIPPING WEIGHT: 62,380 lbs

BUILDER: Skadoc Submersible Systems, Yerseke, Netherlands

SMT.1 and .2

DEPTH: 1,200'
DIMENSIONS (LxWxH): SMT.1: 85" x 50" x 50"; SMT.2: 132" x 60" x 78"
WEIGHT: SMT.1: 2,200 lbs; SMT.2: 4,500 lbs

SPEED: (Max Surface) 5 kts
(Max Current) 1.5 kts at max depth
STRUCTURE: Rectangular-shaped open Al framework encloses and supports all components.

PROPULSION: Four variable-pitch reversible, 7 hp, electro-hydraulic thrusters in Kort nozzles (2 long, 1 lat, 1 vert).

INSTRUMENTATION: Two low light CCTV cameras (one on bow tilt unit, one fixed stern mount), one vidicon CCTV camera on p&t or manipulator, three 500W quartz iodide lights, stereo still cameras with strobe light, echo sounder, pinger, mag compass, depthometer, cp probe, ultrasonic thickness probe, radiographic inspection device, water jet cleaner. Two hydraulic manipulators: one with 4 DOF, one with 7 DOF.

POWER REQ: 440VAC, 60Hz, 3Ø.

SHIPBOARD COMPONENTS: Control console, diesel generator, reel winch, launch/retrieval device.

SUPPORT VESSEL REQ: Deck space: Approx 200 sq ft; cabin space: 100 sq ft

CREW: 7
TOTAL SHIPPING VOL: 1.5 A-2 air cargo modules

TOTAL SHIPPING WEIGHT: SMT.1: 6,125 lbs; SMT.2: Approx 8,400 lbs

BUILDER: International Submarine Engineering Ltd., Port Moody, B.C., Canada

COMMENTS: SMT vehicles are modified ISE Trovs outfit and certified for offshore platform operations. Vehicle can work directly from platform and is suited for a variety of platform inspection and maintenance-related tasks.

SPIDER

DEPTH: 820' (presently limited by umbilical length)
DIMENSIONS (LxWxH): 91" diameter x 79" high
WEIGHT: Approx 3.5 tons

SPEED: (Max Surface) NA
(Max Current) NA
STRUCTURE: SPIDER is an underwater vehicle in the form of a controlled lifting hook, generally cylindrical in shape.

PROPULSION: Vehicle is designed for limited maneuverability of heavy objects and operates on the end of cable in a non-buoyant mode. Three thrusters mounted in 120^{o} horizontal array on vehicle periphery allow lateral and rotational movement. Control is by electro-hydraulic servo. Propulsion power rating of vehicle is 80 hp.
INSTRUMENTATION: Two CCTV cameras on p&t unit, three 250W lights, gyrocompass rate gyro, depthometer, altimeter.

POWER REQ: 440VAC, 60Hz, 60KW

SHIPBOARD COMPONENTS: Control console, handling system, power supply.

SUPPORT VESSEL REQ: Deck space: 8' x 14' for handling system, 8' x 10' for operator's console; vessel capable of handling 3.5 tons over side or stern.

CREW: 3
TOTAL SHIPPING VOL: 1,280

TOTAL SHIPPING WEIGHT: NA

BUILDER: Myrens, Verksted A/S, Oslo, Norway

TOM 300
(Tethered Observation and Manipulation Unmanned Vehicle, 300m)

DEPTH: 1,000'
DIMENSIONS (LxWxH): 142" x 67" x 72"
WEIGHT: Approx 6,600 lbs

SPEED: (Max Surface) 3 kts
(Max Current) 1.5 kts
STRUCTURE: Open Al tubular framework encloses and supports all components. Syntactic foam attached to top of framework provides slightly positive buoyancy.

PROPULSION: Six variable thrust electric propulsion units (3 long, 2 transverse, 1 vert) with 135 lb thrust each.

INSTRUMENTATION: Two B&W CCTV cameras (one fixed for navigation, one on p&t unit for observation), six 500W halogen spotlights, two 250W lights, 35mm still camera with 100 ws strobe, cine camera. One hydraulic manipulator with 3 DOF, 3.6' reach, 110 lb lift capacity. Gyrocompass, depthometer, altimeter, mag compass.

POWER REQ: 220/380/440VAC, 50/60Hz, 3Ø, 100KVA

SHIPBOARD COMPONENTS: Control cabin, cable storage drum, and launch/retrieval device.

SUPPORT VESSEL REQ: Deck space for control cabin, cable drum, and launch/retrieval operations.

CREW: 4
TOTAL SHIPPING VOL: 1,483 cu ft

TOTAL SHIPPING WEIGHT: 15.4 tons

BUILDER: Comex, Marseille, France, and Thomson CSF, Brest, France

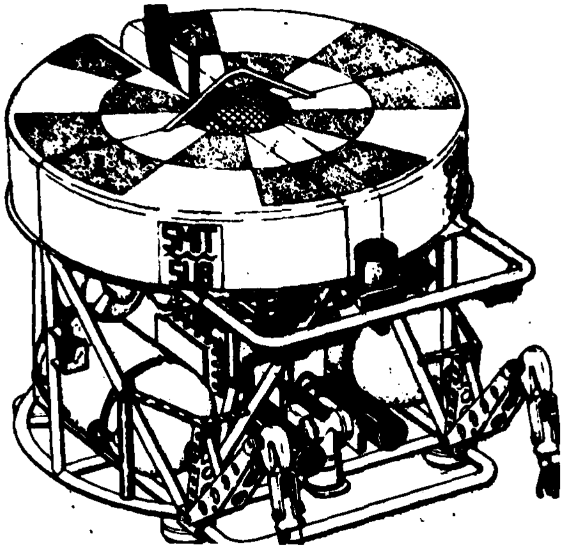


FIGURE B.20 - SMIT SUB 1000
Courtesy of: Skadoc Submersible Systems

FIGURE B.21 - SMT 2
Courtesy of: I.S.E.

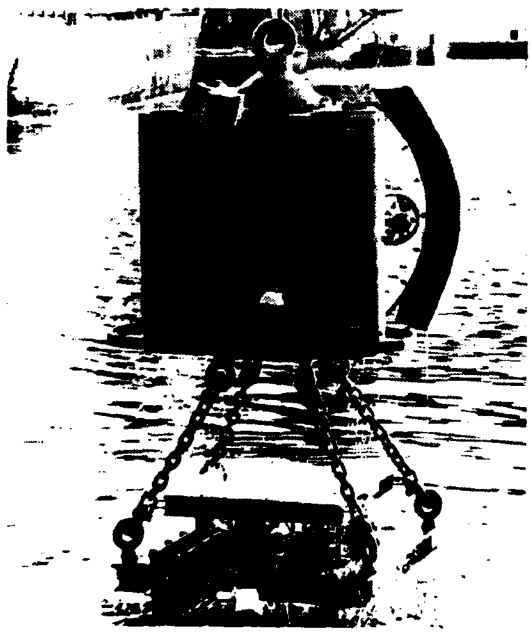


FIGURE B.22 - SPIDER
Courtesy of: Myrens Verksted A/S

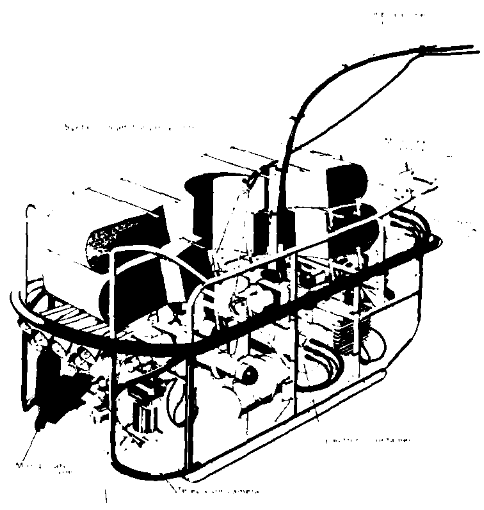


FIGURE B.23 - TOM 300
Courtesy of: COMEX SEAL

TROV 5
(Tethered Remotely Operated Vehicle)

DEPTH: 1,200'
DIMENSIONS (LxWxH): 108" x 50" x 50"
WEIGHT: 3,300 lbs

SPEED: (Max Surface) 3 kts
(Max Current) 1 kt @ max depth

STRUCTURE: Open, rectangular-shaped framework encloses and supports all components. Frame, secondary structure, and containers of 6061-T6 Al. Neutral buoyancy achieved by 35 cu ft of syntactic foam on top of framework. Variable ballast tank for trim.

PROPULSION: Four 7 hp electric motors for reversible ducted propellers (2 long, 1 lat, 1 vert).

INSTRUMENTATION: Two CCTV, three boom-mounted 1500W lights, mag or gyro compass, depthometer, echo sounder, directional hydrophone, xenon flasher, pinger. Two hydraulic back-hoe manipulators, one with 7 DOF, one with 4 DOF, each with 6" claw. Arms fabricated from 6061-T6 Al, stainless steel and brass.

POWER REQ: 440VAC, 60Hz, 3Ø, 55KW provided by diesel generator.

SHIPBOARD COMPONENTS: Control console and power pack, cable winch, spare power pack (batteries) for vehicle, air supply of 200 cu ft at 2,500 psi, power supply.

SUPPORT VESSEL REQ: Deck space: 400 sq ft, launch/retrieval device.

CREW: 4
TOTAL SHIPPING VOL: NA

TOTAL SHIPPING WEIGHT: Approx 5,200 lbs

BUILDER: International Submarine Engineering Ltd., 2601 Murray St., Port Moody, B.C. V3H IXI, Canada

COMMENTS: ISE has built at least ten TROV vehicles. TROV 5 was sold to Sonarmarine and refit as SMT.2. There are wide variations in size and weight as well as instrumentation components, among the various vehicles, subject to buyer specification.

TRUCS
(Tethered Remote Underwater Construction Submersible

DEPTH: 3,000'
DIMENSIONS (LxWxH): 78" x 84" x 264"
WEIGHT: 12,000 lbs

SPEED: (Max Surface) NA
(Max Current) NA
STRUCTURE: Rectangular-shaped framework which encloses and supports all components. Framework constructed of 6061-T6 Al and 316 stainless steel. Buoyancy provided by syntactic foam and blowable air ballast tanks.

PROPULSION: Six variable pitch propeller thrusters (2 long, 2 lat, 2 vert) all 50 or 100 hp each. Propulsion for payloads up to 20,000 lbs.

INSTRUMENTATION: Four CCTV (3 B&W, 1 color), up to 10,000W lighting, echo sounder, auto depth function, tracking system, gyro compass, xenon flasher, directional hydrophone. Two manipulators with 4, 5, 6, or 7 DOF. Optional equipment includes auto pilot, various sonars, jet pump, hydraulic tools, etc.

POWER REQ: 480VAC, 60Hz, 3Ø, 400 to 1,000KVA.

SHIPBOARD COMPONENTS: NA

SUPPORT VESSEL REQ: NA

CREW: NA
TOTAL SHIPPING VOL: NA

TOTAL SHIPPING WEIGHT: NA

BUILDER: International Submarine Engineering Ltd., 2601 Murray St., Port Moody, B.C. V3H IXI, Canada
COMMENTS: Construction of the prototype TRUCS is not yet complete. It is designed for heavy work tasks and carrying large payloads. Design configuration and instrumentation is flexible.

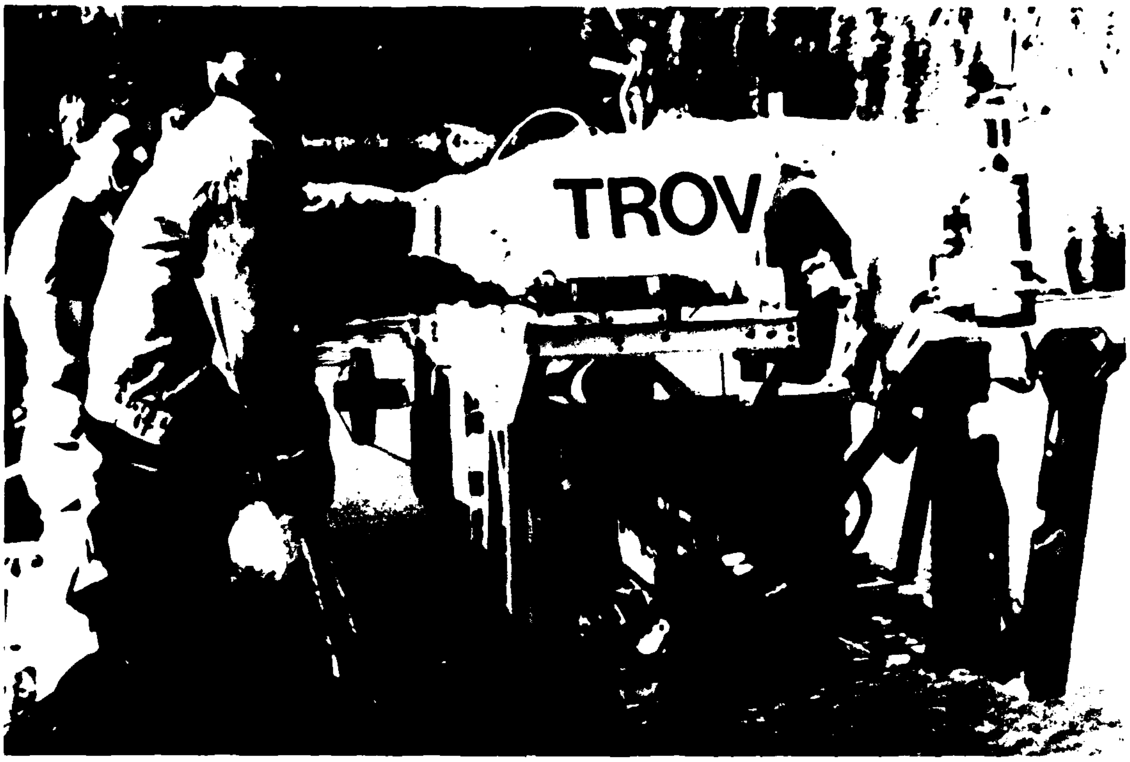


FIGURE B.24 - TROV
Courtesy of: International Submarine Engineering

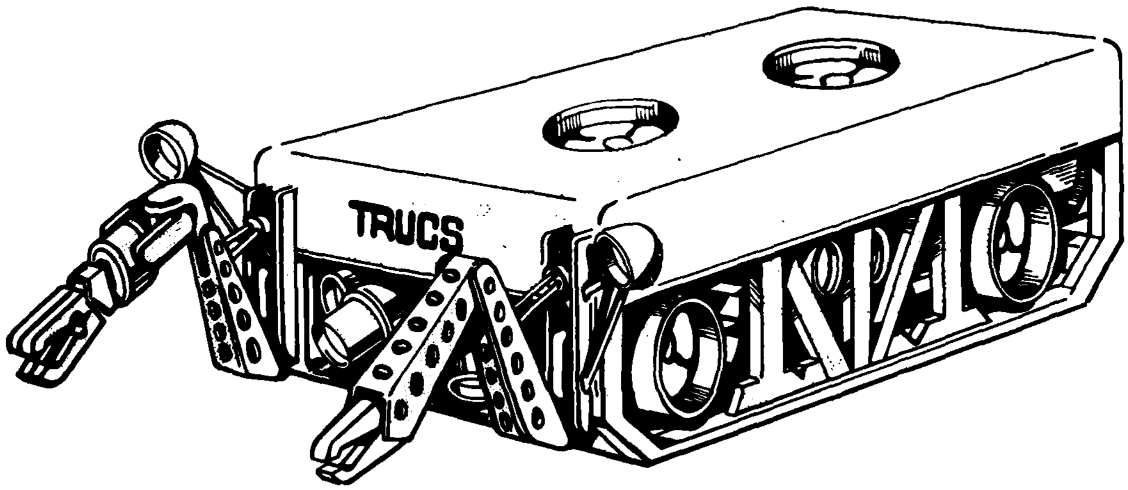


FIGURE B.25 - TRUCS
Courtesy of: International Submarine Engineering

MANIPULATOR OPTIONAL VEHICLES

BOCTOPUS

DEPTH: 2,170'
DIMENSIONS (LxWxH): 126" x 84" x 66"
WEIGHT: 2,140 lbs

SPEED: (Max Surface) 2.5 kts
(Max Current) 2.0 kts @ 1,150'

STRUCTURE: Rectangular-shaped open steel framework which encloses and supports all components. Upper half of vehicle is covered with fiberglass fairing which also contains buoyant spheres to achieve a 20 lb positive buoyancy for operation.

PROPULSION: Five thrusters: two 10 hp, longitudinal ducted thrusters, two 4 hp, vertical ducted thrusters, one 3 hp lateral ducted thruster.

INSTRUMENTATION: Two CCTV (one pilot camera fixed, one observation camera on p&t unit), mag compass, pressure transducer, two lights, echo sounder, transponder. Vehicle is designed to accommodate side-scan sonar, and sub-bottom profiler. Optional equipment includes cine camera, still camera, and manipulator.

POWER REQ: NA

SHIPBOARD COMPONENTS: Diesel generator, control cabin, hydraulic crane and winch.

SUPPORT VESSEL REQ: Launch/retrieval system, bow thruster, twin screws, deck space for vehicle and control cabin.

CREW: 4
TOTAL SHIPPING VOL: 2,154 cu ft

TOTAL SHIPPING WEIGHT: 12.5 tons

BUILDER: BOC Ltd., New Venture Secretariat, Hammersmith House, London W6 9DX, England

RECON III

DEPTH: 1,000'
DIMENSIONS (LxWxH): 60" x 30" x 29"
WEIGHT: 380 lbs

SPEED: (Max Surface) 2.5 kts
(Max Current) NA
STRUCTURE: Rectangular-shaped tubular metal framework which encloses and supports all components. Solid syntactic foam block provides buoyancy.

PROPULSION: Five electric thrusters: 2 horizontal proportionally controlled, 40 lbs thrust each; 1 vert proportionally controlled, 40 lbs thrust, feedback loop to auto depth control; 2 lat on/off thrusters providing 14 lbs of thrust each.

INSTRUMENTATION: CCTV (Subsea CM8-BL, B&W) with two 250W Mercury vapor lights on p&t unit, auto depth and heading control, mag compass. Optional equipment includes electric grabber arm with 2 DOF, 20 lb lifting capability; navigation system (Honeywell RS-7), still photography system, cp probe.

POWER REQ: 208/220/440VAC, 60Hz, 3Ø, 15KVA.

SHIPBOARD COMPONENTS: Control console, optional control van, transformer, launch/retrieval system.

SUPPORT VESSEL REQ: Deck space: 40 sq ft for control station, 500 sq ft for launching area and winch.

CREW: 3
TOTAL SHIPPING VOL: 136 cu ft

TOTAL SHIPPING WEIGHT: 1,850 lbs

BUILDER: Perry Oceanographics, Inc., 100E 17th St., Riviera Beach, FL 33404

COMMENTS: Update of RECON II vehicle system.

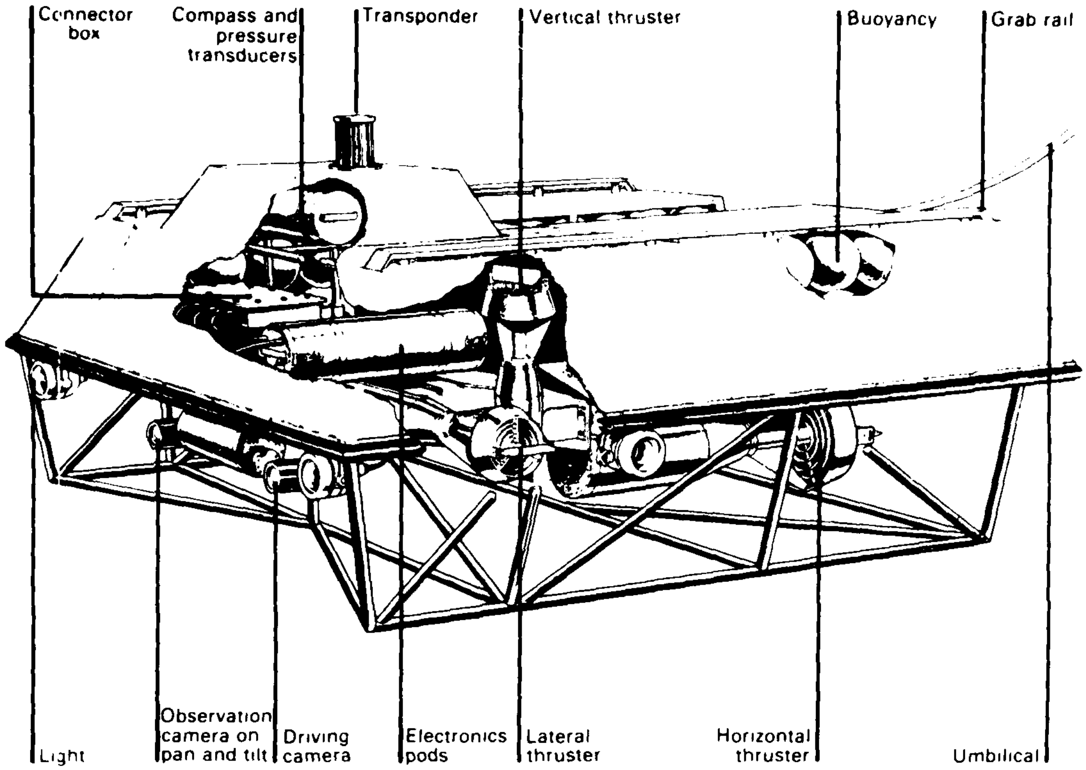


FIGURE B.26 - BOCTOPUS
Courtesy of: BOC Ltd.

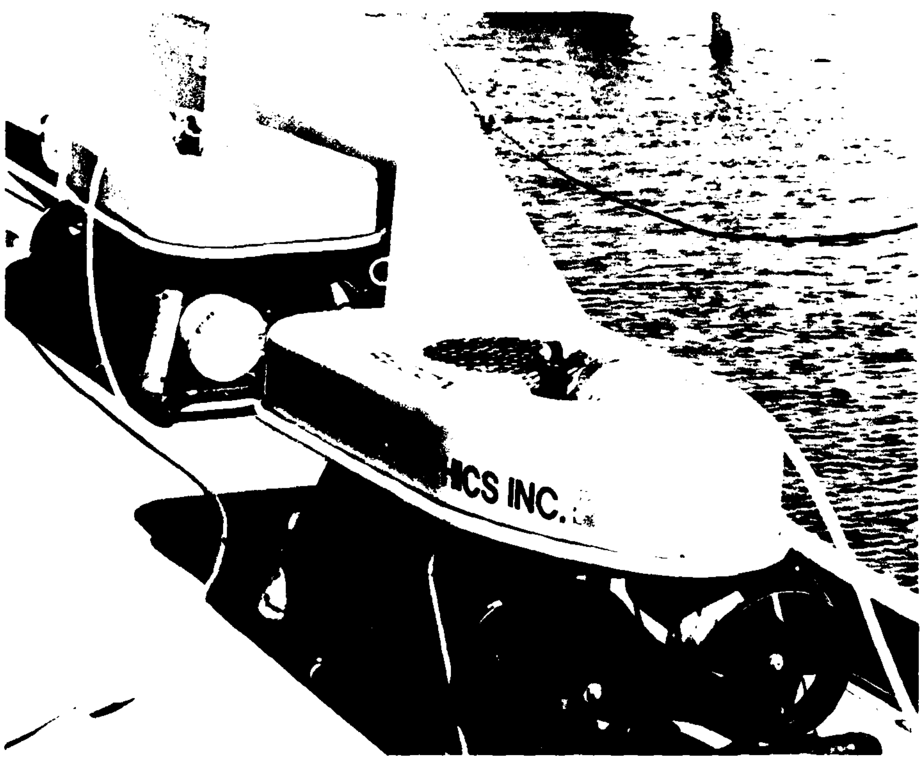


FIGURE B.27a - RECON III
Courtesy of: Perry Oceanographics, Inc.

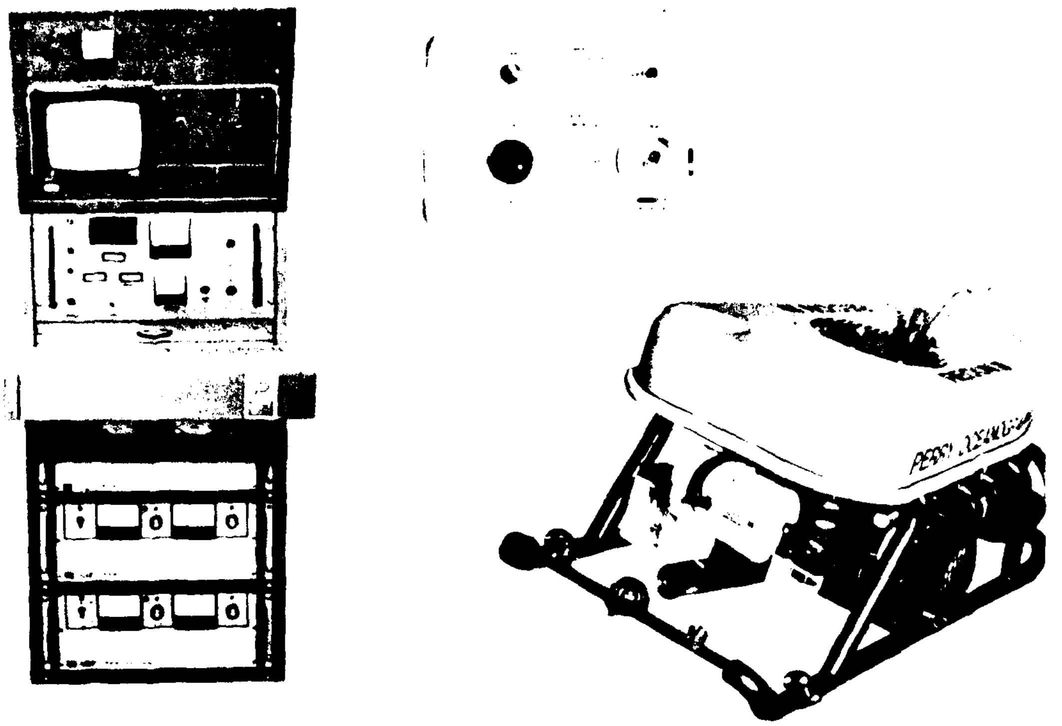


FIGURE B.27b - RECON III CONTROL CONSOLE, REMOTE CONSOLETTE, AND VEHICLE
Courtesy of: Perry Oceanographics, Inc.

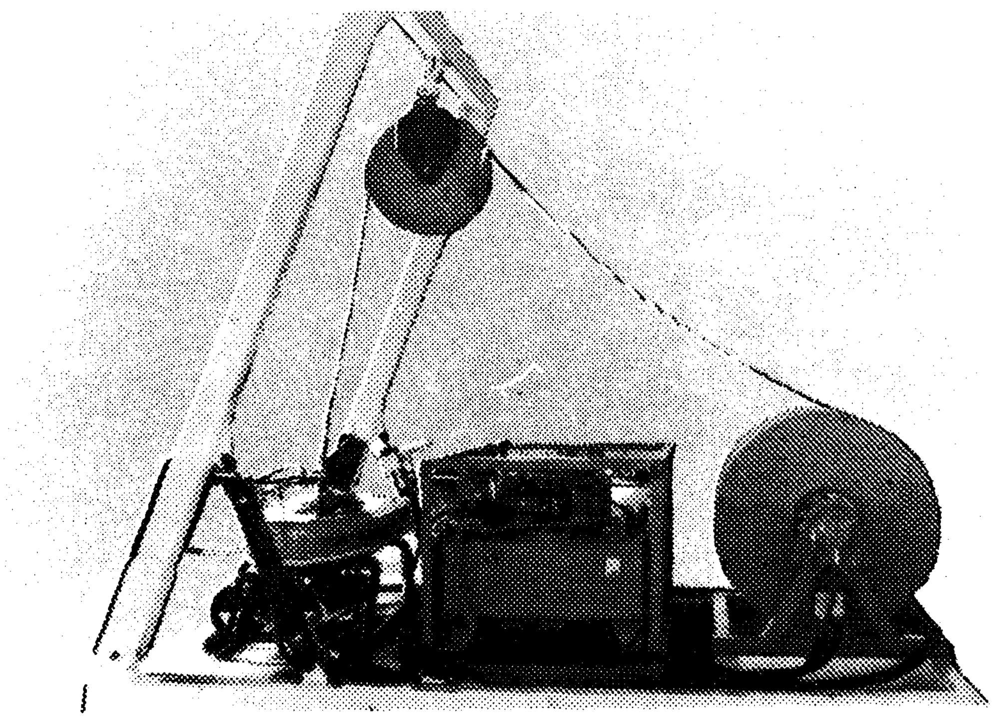


FIGURE B.27c - RECON III LAUNCH/RETRIEVAL SYSTEM
Courtesy of: Perry Oceanographics, Inc.

SNURRE II

DEPTH: 1,640'
DIMENSIONS (LxWxH): 126" x 75" x 71"
WEIGHT: Approx 2,500 lbs

SPEED: (Max Surface) NA
(Max Current) NA
STRUCTURE: Open Al framework which encloses and supports all components. Six fiberglass-reinforced spheres attached to top of frame provide neutral buoyancy. Four additional spheres providing up to 400 lbs positive buoyancy may be added for additional payload.

PROPULSION: Four reversible hydraulic thrusters (1 vert, 3 in 120^{o} triangular arrangement providing motion in all horizontal directions) with approximately 290 lbs thrust each.

INSTRUMENTATION: Low light level CCTV on tilt unit for pilot, vidicon CCTV, and still camera on p&t unit for inspection, five 250W lights, depthometer, altimeter, rate gyro for rotational stability, gyro compass, scanning sonar. Optional equipment includes hydraulic manipulator (either on-off or proportional control type), water jet, bottom profiler, current meter.

POWER REQ: 440VAC, 60Hz

SHIPBOARD COMPONENTS: Operator's console (in 8' x 20' container), generator, cable winch, launch/retrieval device.

SUPPORT VESSEL REQ: Deck space: 8' x 20' for control van; 8' x 14' for umbilical handing van; 13' x 20' for vehicle.

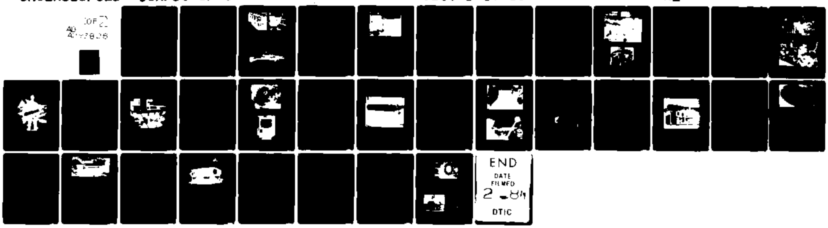
CREW: 4-5
TOTAL SHIPPING VOL: Two 20' standard (ISO) cargo containers.

TOTAL SHIPPING WEIGHT: Approx 11 tons

BUILDER: Myren Verksted A/S. PO Box 4200, Torshov, Oslo 4, Norway

COMMENTS: Initial development of Snurre undertaken by Continental Shelf Institute of Trondheim, Norway. Myrens continues development for production and marketing under license. Vehicle designed for observation, inspection, and light work tasks.

AD-A093 826 COAST GUARD RESEARCH AND DEVELOPMENT CENTER GROTON CT F/G 13/2
STATE-OF-THE-ART SURVEY OF HARDWARE DELIVERY AND DAMAGE INSPECT--ETC(U)
AUG 80 R T WALKER
UNCLASSIFIED CGR/DC-5/80 USCG-D-67-80 NL



TREC
(Tethered Remote Camera)

DEPTH: 1,200'
DIMENSIONS (LxWxH): 45" x 35" x 38"
WEIGHT: 350 lbs

SPEED: (Max Surface) 2 kts
(Max Current) 1.5-2.0 kts
STRUCTURE: Open rectangular-shaped framework encloses and supports all components. Frame, secondary structure, and containers in 6061-T6 Al. Neutral buoyancy achieved with syntactic foam attached to top of frame. Variable ballast trim tank.

PROPULSION: Five reversible 1.25 hp electric thrusters (2 long, 1 lat, 2 vert).

INSTRUMENTATION: Low light CCTV camera on p&t mount, two variable intensity 1000W lights, depthometer, mag compass, xenon flasher. Optional equipment includes: manipulator with 3 DOF and 6" claw, gyro compass, stereo CCTV, color CCTV, still camera, pinger, etc.

POWER REQ: 120VAC, 60Hz, 1Ø, 6KVA provided by diesel generator.

SHIPBOARD COMPONENTS: Control console, cable reel, generator, launch/retrieval device.

SUPPORT VESSEL REQ: Deck space: 30' x 20', launch/retrieval device.

CREW: 2
TOTAL SHIPPING VOL: 120 cu ft

TOTAL SHIPPING WEIGHT: 1,000 lbs

BUILDER: International Submarine Engineering Ltd., 2601 Murray St., Port Moody, B.C. V3H 1X1, Canada

SEA INSPECTOR

DEPTH: 3,280'
DIMENSIONS (LxWxH): 132" x 47" x 24"
WEIGHT: 309 lbs

SPEED: (Max Surface) 5 kts
(Max Current) 3 kts
STRUCTURE: Metal torpedo-shaped body with stern-mounted propeller and forward-mounted dive planes.

PROPULSION: 2 hp motor drives stern-mounted propeller.

INSTRUMENTATION: CCTV (color) and light mounted forward, 16mm cine camera or 35mm still camera, auto depth and heading, control unit, depthometer, compass, rearward-looking mini CCTV camera to monitor umbilical cable. Optional equipment includes scanning sonar, side-looking sonar, magnetometer, small 4 DOF manipulator with parallel swivel claw.

POWER REQ: 230VAC, 60Hz, 4KW.

SHIPBOARD COMPONENTS: Control console, handling system, power supply.

SUPPORT VESSEL REQ: Stationkeeping ability for live boat operations.

CREW: 2
TOTAL SHIPPING VOL: NA

TOTAL SHIPPING WEIGHT: NA

BUILDER: Rebikoff Underwater Products, Inc., Ft. Lauderdale, FL

COMMENTS: This vehicles uses dynamic control surfaces to effect vertical movement rather than vertically oriented thrusters. Inspection of vertical surfaces with this vehicle would be difficult.

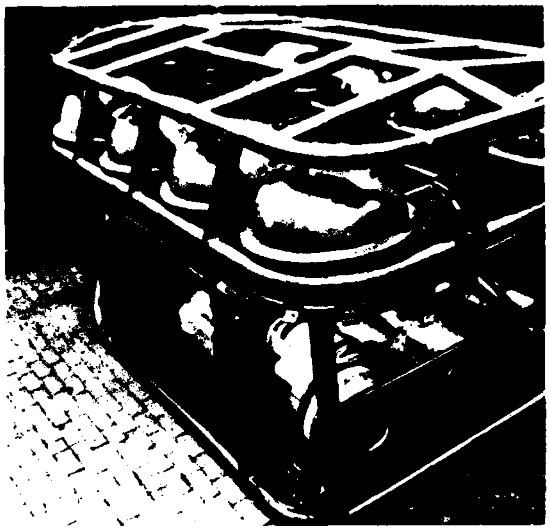


FIGURE B.28 - SNURRE II
Courtesy of: Myrens Verksted A/S

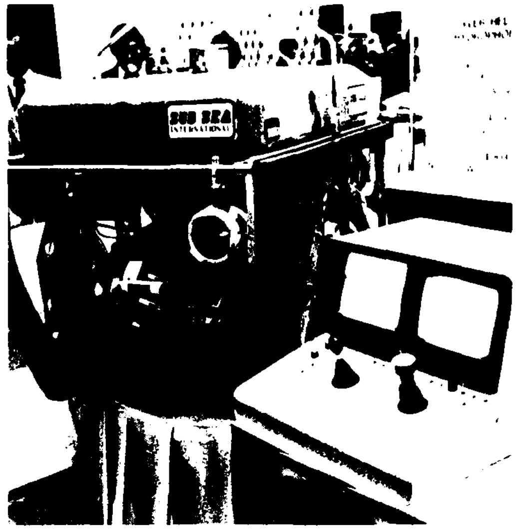


FIGURE B.29 - TREC
Courtesy of: International Submarine Engineering

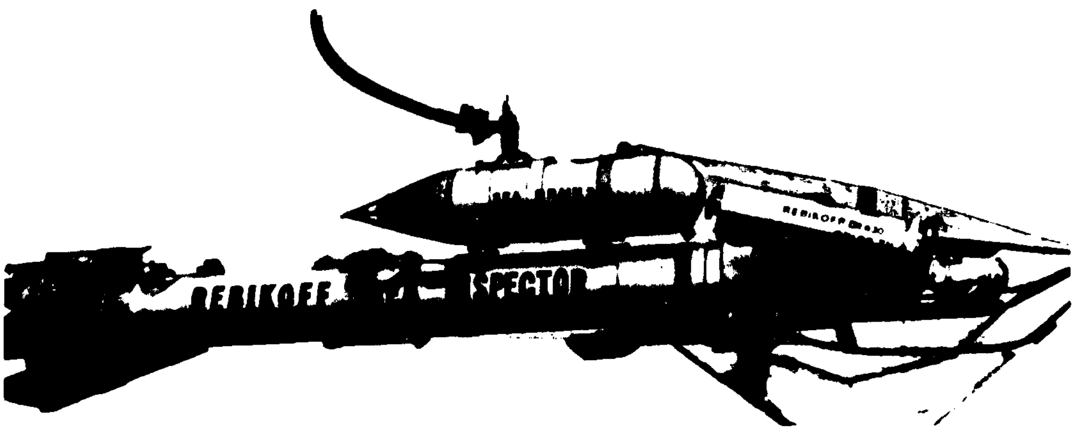


FIGURE B.30 - SEA INSPECTOR
Courtesy of Rebikoff Underwater Products, Inc.

TELESUB 1000

DEPTH: 2000'
DIMENSIONS (LxWxH): 55" x 31" x 27"
WEIGHT: 550 lbs

SPEED: (Max Surface) 2.3 kts
(Max Current) 1.5 kts @ 1000' no clump; 2 kts with clump

STRUCTURE: Rectangular-shaped, open Al framework encloses and supports all components. Syntactic foam mounted on top of frame provides slight positive buoyancy.

PROPULSION: Four, ducted, variable-speed thrusters (2 long, 1 lat, 1 vert) providing 75 lbs thrust each.

INSTRUMENTATION: CCTV camera with wide angle lens. Two 500W quartz iodide lights, leak detector, mag compass, depthometer, latching device and line reel. Standard options include auto depth control, auto heading lock, tether shearer, still photo camera, stereo TV system, sonar and tracking systems, manipulative or inspection devices.

POWER REQ: 200 or 440VAC, 60Hz, 12KVA

SHIPBOARD COMPONENTS: Power distribution unit, cable bin, control box, TV monitor, power supply.

SUPPORT VESSEL REQ: Handling device, deck space for vehicle, power supply and distribution unit, cable bin; cabin space for control box, operator and TV monitor.

CREW: 2
TOTAL SHIPPING VOL: 38.4 sq ft

TOTAL SHIPPING WEIGHT: 1,060 lbs

BUILDER: Remote Ocean Systems, Inc., PO Box 699, Escondido, CA 92025

COMMENTS: Single prototype vehicle is on long-term lease. Lease holder has first option to buy. Vehicle does not currently have a manipulator device.

FIGURE B.31a - TELESUB 1000
Courtesy of: Remote Ocean Systems, Inc.

TELESUB™ 1000 SYSTEM

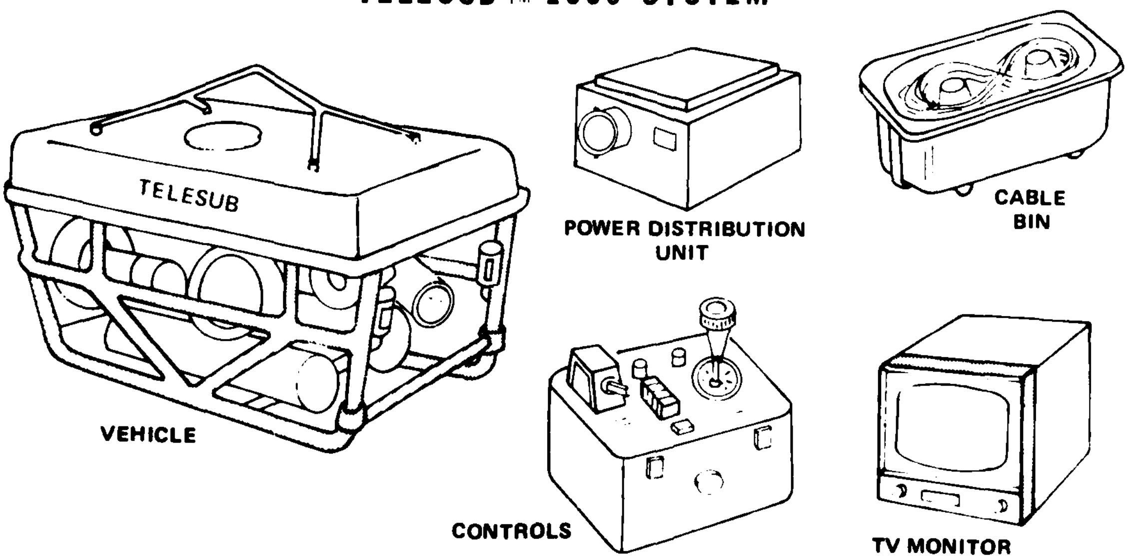


FIGURE B.31b - TELESUB 1000 SYSTEM
Courtesy of: Remote Ocean Systems, Inc.

APPENDIX C

OBSERVATION AND SHIP HUSBANDRY ROV SPECIFICATIONS

ANGUS 002
(A Navigable General-Purpose Underwater Surveyor)

DEPTH: 984'
DIMENSIONS (LxWxH): 90" x 51" x 55"
WEIGHT: 1,540 lbs

SPEED: (Max Surface) 2.0 kts
(Max Current) 1.0 kt @ max depth
STRUCTURE: Open tubular Al framework encloses and supports all components. Slight positive buoyancy provided by 8" polypropylene floats contained in glass reinforced casing attached to the top of the frame.

PROPULSION: Two 4.5 hp longitudinal thrusters mounted on stern and four 1.5 hp vertical thrusters ducted through upper casing corners.

INSTRUMENTATION: Two CCTV (one fixed for pilot, one on p&t unit for observation), two 650W lights, one 500W light, 35mm still camera, super 8mm cine camera, 25KHz hydrophone, wide band hydrophone, mag compass, echo sounder, pressure transducers, two 160 joule strobe lights, tracking system.

POWER REQ: 415/240VAC, 50Hz, 3Ø, 20KVA supplied by diesel generator.

SHIPBOARD COMPONENTS: Generator, earth leakage protection unit, control console, cable reels, navigation console, transponders.

SUPPORT VESSEL REQ: Any vessel over 75' long with derrick capable of lifting vehicle weight over the side.

CREW: 2
TOTAL SHIPPING VOL: 783 cu ft

TOTAL SHIPPING WEIGHT: 3.5 tons

BUILDER: Heriot-Watt University, Dept. of Electrical and Electronic Engineering, 31-35 Grassmarket, Edinburgh, EH1 2HT, Scotland
COMMENTS: Designed to carry out seabed surveys, inspection, and small object/sample recovery missions. Vehicle is inherently very stable. Available for charter.

AUGUS 003

DEPTH: 984'
DIMENSIONS (LxWxH): 94" x 59" x 59"
WEIGHT: 2,200 lbs

SPEED: (Max Surface) Approx 3.5 kts
(Max Current) Approx 2.0 kts @ max depth
STRUCTURE: Open tubular Al framework encloses and supports all components. Plastic floats within glass reinforced casing on top of frame provide buoyancy.

PROPULSION: Two 6 hp reversible induction motors with Kort nozzles, provide horizontal thrust. Four 2 hp reversible induction motors provide vertical thrust. Four 1.25 hp reversible induction motors with Kort nozzles provide lateral thrust.

INSTRUMENTATION: Two CCTV cameras (one fixed for pilot, one on p&t unit for observation), 35mm still camera, 16mm or 8mm cine camera, pressure transducers, wide band hydrophone, up and down looking sonar, thermometer, mag compass, obstacle avoidance sonar, tracking system, four 650W lights, one 500W light.

POWER REQ: 240/440VAC, 50Hz, 3Ø, either from portable generator or ship's power.

SHIPBOARD COMPONENTS: Power supply, control console, cable reels, navigation console and transponders, earth leakage protection unit.

SUPPORT VESSEL REQ: Any vessel over 75' long with derrick capable of handling vehicle weight over the sides.

CREW: NA
TOTAL SHIPPING VOL: NA

TOTAL SHIPPING WEIGHT: NA

BUILDER: Heriot-Watt University, Dept. of Electrical and Electronic Engineering, 31-35 Grassmarket, Edinburgh, EH1 2HT, Scotland
COMMENTS: Vehicle was intended as a backup for ANGUS 002, however, operational experience indicated some major modifications would be beneficial. Major change was increased power available to thrusters and the addition of lateral thrusters for operations in cross currents up to 3 kts.

FIGURE C.1 - ANGUS 002
Courtesy of: Heriot-Watt University

FIGURE C.2 - ANGUS 003
Courtesy of: Heriot-Watt University

CONSUB I

DEPTH: 2000'
DIMENSIONS (LxWxH): 107" x 72" x 57"
WEIGHT: 3,000 lbs

SPEED: (Max Surface) 2.5 kts
(Max Current) 2 kts @ max depth
STRUCTURE: Open framework constructed of tubular Al alloy HE130. Up to 40 lbs positive buoyancy provided by two pressure-resistant fiberglass cylinders.

PROPULSION: Four electro-hydraulic reversible thrusters (2 lat, 2 fixed vert) 5 hp each, independently operable.

INSTRUMENTATION: Two CCTVs (1 color, 1 B&W) and stereo camera all mounted on pan and tilt unit, rock drill, mag compass, inclinometer, depth gauge.

POWER REQ: 240V, 50Hz, 1Ø, 3KVA; 415V, 50Hz, 3Ø, 50KVA to control cabin transformer. If the latter is not available, a diesel generator can be used. Surface transformer converts supply V to 415V/1000V, 3Ø for vehicle.

SHIPBOARD COMPONENTS: Control console (2 TV monitors, vehicle and instrument controls), transformer, system distribution box (connects transformer, ship junction box and consoles), ship junction box (terminates umbilical cable of support craft) and umbilical storage frame.

SUPPORT VESSEL REQ: Launch/retrieval system capable of handling 3,000 lbs. Freeboard less than 12 ft. Deck space: 10' x 10' for vehicle, 20' x 20' area for umbilical frame. Cabin space: for 7' long console, 2' x 2' floor space for transformer, 3' x 4' floor space for distribution box.
CREW: 3 to 4
TOTAL SHIPPING VOL: NA

TOTAL SHIPPING WEIGHT: Approx 6,100 lbs

BUILDER: Constructed by British Aircraft Corp., Ltd., Bristol, England

COMMENTS: Developed for Institute of Geological Sciences for making visual survey of UK continental shelf and rock coring. Also suitable for inspection of pipelines, cables, and structures. Available for hire from BAC when not in use by IGS.

DART
(Deep Access Reconnaissance Television)

DEPTH: 1,200'
DIMENSIONS (LxWxH): 40" x 18" x 12"
WEIGHT: 100 lbs

SPEED: (Max Surface) 4 kts
(Max Current) NA
STRUCTURE: Rectangular configuration with 6061-T6 Al and 316 stainless subframe. PVC buoyancy cylinders located on top of vehicle.

PROPULSION: Four thrusters (2 long, 1 lat, 1 vert) deliver 25 lbs thrust each.

INSTRUMENTATION: CCTV with pan and tilt lens, two 250W variable intensity quartz halogen lights, depth sensor, compass. Optional equipment includes still camera, pinger, xenon flasher, auto heading, tracking system, cp probe.

POWER REQ: 120VAC, 60Hz, 1Ø, 2.5KW

SHIPBOARD COMPONENTS: Control console (19" x 20" x 15", 80 lbs), power supply.

SUPPORT VESSEL REQ: Space for operator and control console.

CREW: 1
TOTAL SHIPPING VOL: Approx 10 cu ft

TOTAL SHIPPING WEIGHT: Approx 350 lbs

BUILDER: International Submarine Engineering Ltd., 2601 Murray St., Port Moody, B.C. V3H IXI, Canada

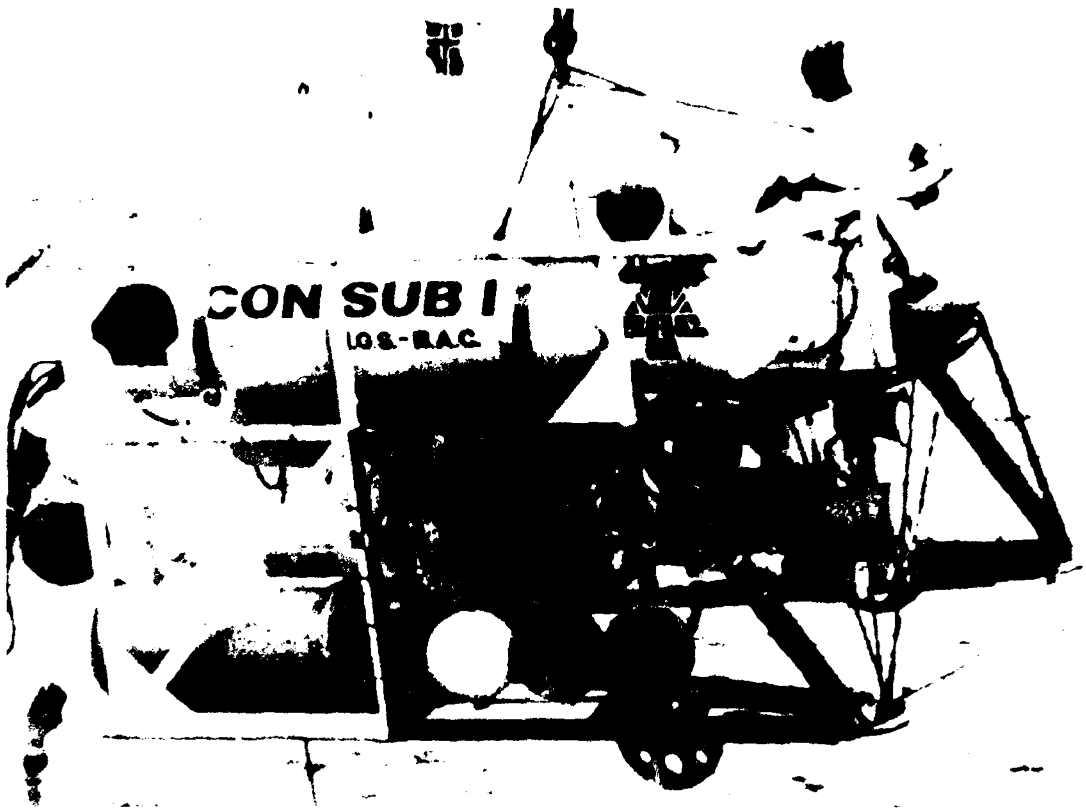


FIGURE C.3 - CONSUB I
Courtesy of: BAC, Ltd.

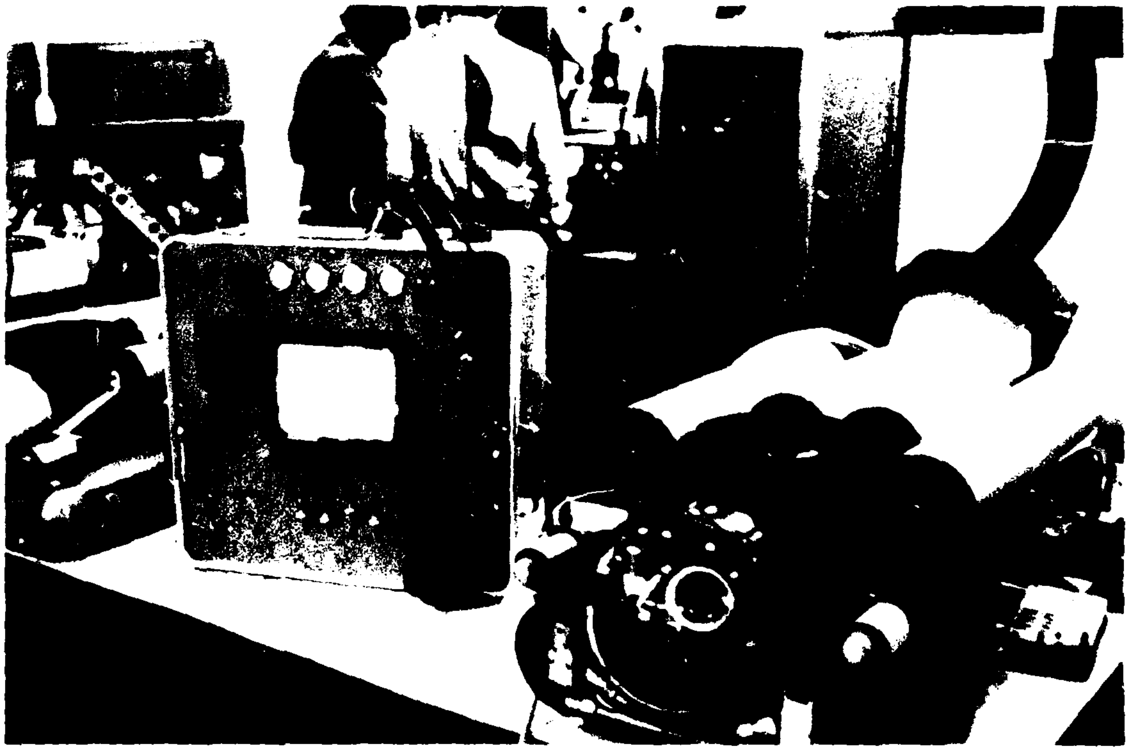


FIGURE C.4 - DART
Courtesy of: International Submarine Engineering

FIGURE C.5 - DART VEHICLE CAN BE HANDLED BY ONE PERSON
Courtesy of International Submarine Engineering

DEEP DRONE

DEPTH: 2,000'
DIMENSIONS (LxWxH): 84" x 48" x 54"
WEIGHT: Approx 1,500 lbs

SPEED: (Max Surface) 3.5 kts
(Max Current) Approx 2 kts @ max depth
STRUCTURE: Open, tubular Al framework encloses and supports all components except sonar units. Two pressure-resistant flotation tanks provide up to 45 lbs positive buoyancy.

PROPULSION: Three fixed reversible 3 hp thrusters (2 long, 1 vert) with Kort nozzles.

INSTRUMENTATION: Two CCTV cameras (one fixed, one on p&t unit), three lights, 70mm still camera with strobe, CTFM sonar and pinger locator, compass, altimeter, depthometer, ATNAV II Subsurface Navigation System.

POWER REQ: 115VAC, 60Hz, 1Ø, 2KVA; 440VAC, 60Hz, 3Ø, 10KVA. All power provided by diesel generator.

SHIPBOARD COMPONENTS: Control console, vehicle locator system, generator, cable basket, launch/retrieval device.

SUPPORT VESSEL REQ: Derrick capable of lifting 1 ton over the side, deck capstan for umbilical handling, stationkeeping ability for live boat operations, 200 sq ft deck space.

CREW: 4 minimum
TOTAL SHIPPING VOL: 4,000 cu ft in two standard LD-9 air cargo containers

TOTAL SHIPPING WEIGHT: 5.5 tons

BUILDER: Ametek, Straza Division, PO Box 666, El Cajon, CA 92022

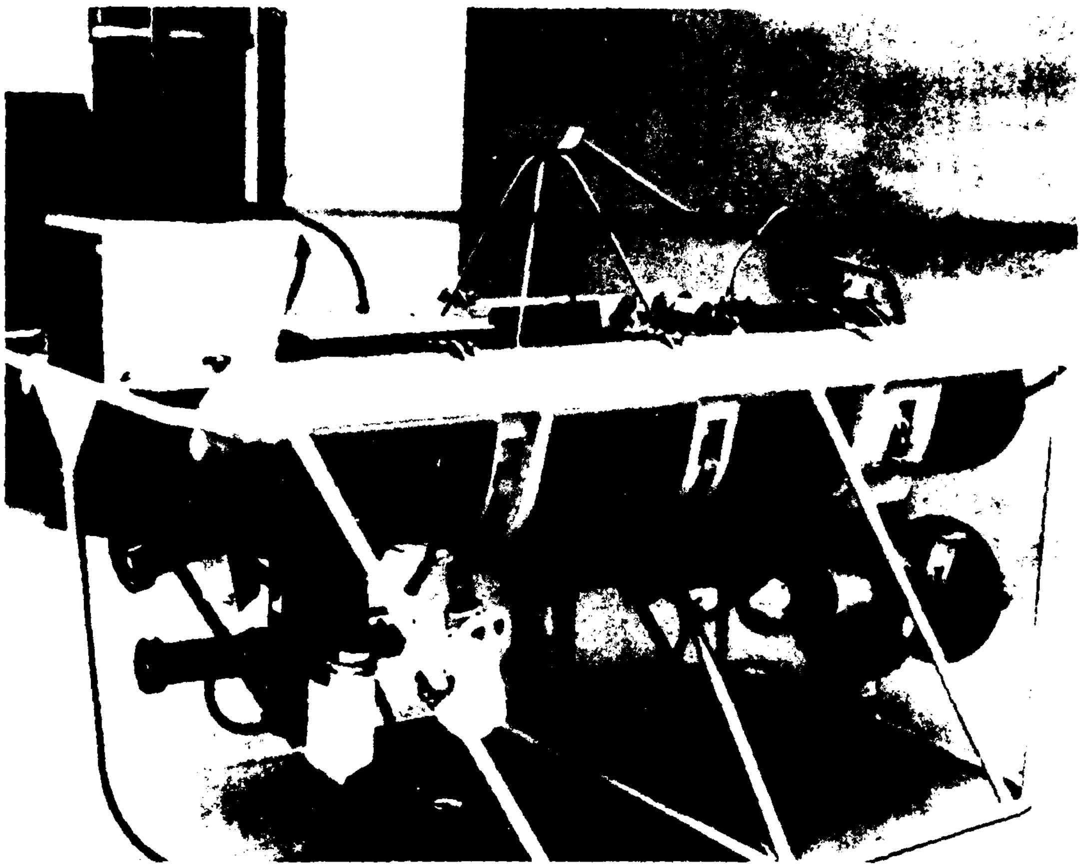


FIGURE C.6 - DEEP DRONE
Courtesy of: Ametek Straza Division

FILIPPO

DEPTH: 984'
DIMENSIONS (LxWxH): Spherical shape with nominal diameter of 26"
WEIGHT: Approx 180 lbs

SPEED: (Max Surface) 1.2 kts
(Max Current) 0.5 kts @ max depth

STRUCTURE: Two hemispherical fiberglass hulls bolt together enclosing and protecting all components. Hull crush depth in excess of 3,000'. Vehicle is nominally neutrally buoyant. May handle up to 8 lbs additional payload depending on shape and size.

PROPULSION: Four separate proportionally controlled DC motors (2 horiz, 2 vert/transverse) with ring guards.

INSTRUMENTATION: CCTV views through one of two flat windows in hull, oriented 30^{o} down from horizontal, one 55W halogen light, mag compass, depthometer. Optional equipment includes 35mm still camera, second CCTV camera viewing through a third flat port in the upward direction, vehicle-mounted sonar.

POWER REQ: All vehicle power is derived from 12V DC 10A supplied by solid gel batteries carried on board in two separate packs, good for approximately 8 hours continuous operation. Rechargeable without opening vehicle.

SHIPBOARD COMPONENTS: Electric cable winch (21" x 20" x 16", 100 lbs with cable), control console (16" x 10" x 12", 22 lbs).

SUPPORT VESSEL REQ: Can be deployed by a single operator from virtually any vessel.

CREW: 1
TOTAL SHIPPING VOL: Approx 15 cu ft

TOTAL SHIPPING WEIGHT: 280 lbs

BUILDER: Gay Underwater Instruments, Ing. Guido Gay, Via Papa Giovanni, 1-20090 Trezzano sul Naviglio, Italy

COMMENTS: FILIPPO is an underwater observation and inspection vehicle of minimum dimensions and cost, designed for batch production. Some literature suggests a manipulator is optional, however, the power available for thruster control and vehicle size make this possibility questionable.

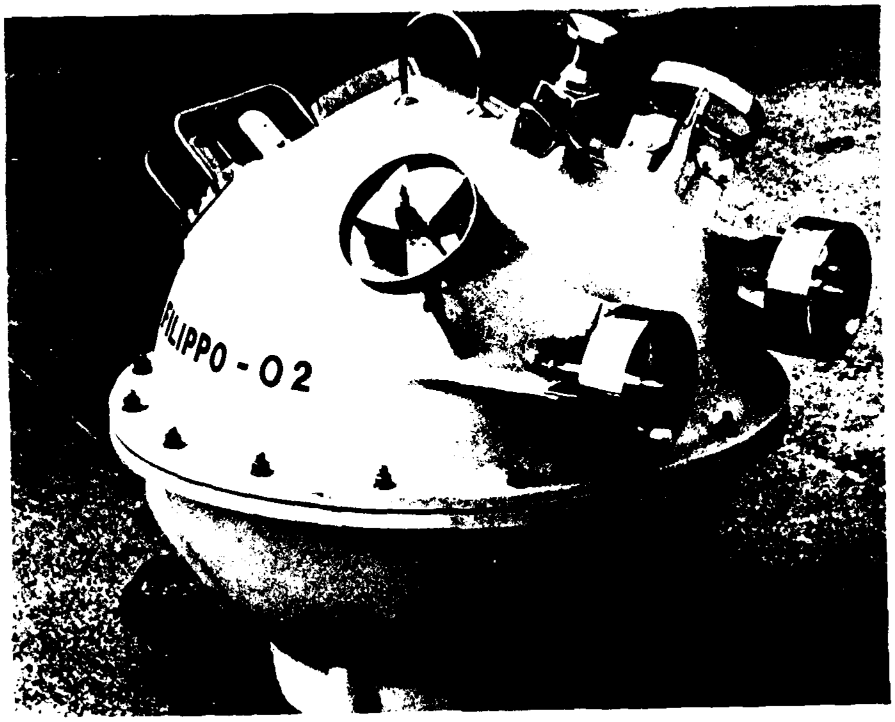


FIGURE C.7a - FILIPPO
Courtesy of: Nereides

FIGURE C.7b - FILIPPO CONTROL UNIT
Courtesy of: Nereides

IZE

DEPTH: 1,640'
DIMENSIONS (LxWxH): 51" x 31" x 20"
WEIGHT: Approx 300 lbs

SPEED: (Max Surface) NA
(Max Current) NA
STRUCTURE: Rectangular-shaped open Al framework. Pressure-resistant cylinders on top of framework provide positive buoyancy and house electronic components, with extra space for additional payload.

PROPULSION: Four 1 hp electric motors (2 long, 1 lat, 1 vert) driving 8" propellers in Kort nozzles.

INSTRUMENTATION: CCTV on p&t unit, one thallium iodide light, two 250W quartz halogen lights, depthometer, acoustic navigation system, transponder, surface flasher. Optional equipment includes trench profiler, side scan sonar, scanning sonar, 35mm still camera and flash, echo sounder, etc.

POWER REQ: 380 to 440VAC, 50/60Hz, 3Ø, 8KW

SHIPBOARD COMPONENTS: Control console, motor controller, cable reel.

SUPPORT VESSEL REQ: Launch/retrieval device capable of lifting vehicle over the side, power supply, deck space for topside components.

CREW: NA
TOTAL SHIPPING VOL: NA

TOTAL SHIPPING WEIGHT: NA

BUILDER: SubSea Surveys, Ltd., Old Bank Chambers, 127 Duke Street, Barrow-in-Furness, Cambria LA 14 1XA, England

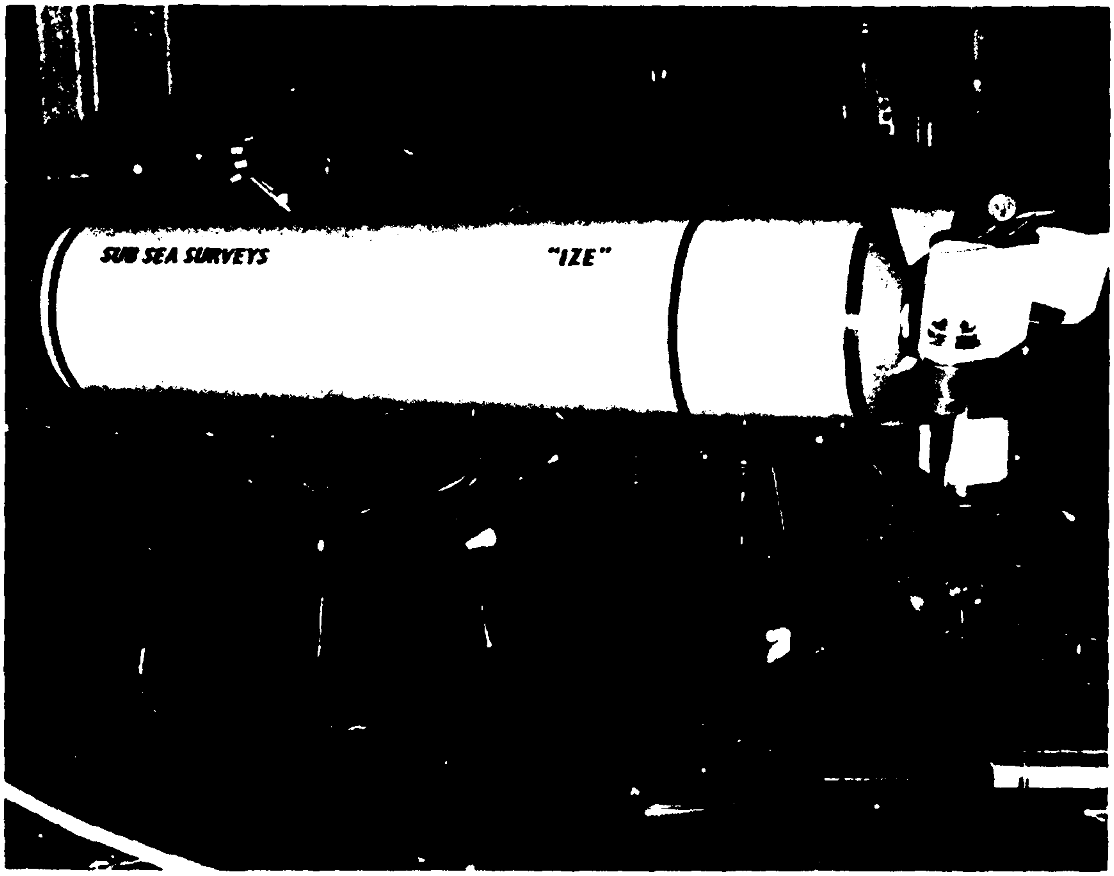


FIGURE C.8 - IZE
Courtesy of: Sub Sea Surveys

RCV 225

DEPTH: 6,600'
DIMENSIONS (LxWxH): 20" x 26" x 20"
WEIGHT: Vehicle: 180 lbs; launcher: 425 lbs

SPEED: (Max Surface) 1.7 kts
(Max Current) 1 kt @ max depth
STRUCTURE: Syntactic foam hull encloses the motors and camera/electronics housing and provides slight (4 lbs) positive buoyancy.

PROPULSION: Four oil-filled electric motors (2 long, 2 vert/transverse) provide three degrees of freedom in translation plus yaw control.

INSTRUMENTATION: Low light level CCTV with tiltable lens, two 45W tungsten halogen lamps, compass, depthometer, auto depth and heading control, tether cable cutter. Still camera system optional.

POWER REQ: 220VAC, 50/60Hz, 3Ø or 440VAC, 50/60Hz, 3Ø, 5KW max

SHIPBOARD COMPONENTS: Control console, power supply, hand controller, launch/retrieval device.

SUPPORT VESSEL REQ: Cabin space for control console, deck space for handling device.

CREW: 2-3
TOTAL SHIPPING VOL: 285 cu ft

TOTAL SHIPPING WEIGHT: 5,555 lbs

BUILDER: Hydro Products, Box 2528, San Diego, CA 92112

COMMENTS: RCV 225 represents the next generation vehicle following the RCV 125. Vehicle is deployed from surface winch in an underwater launcher (3.7' x 3.2' x 3.2') from which it flies out on a 400' tether to perform its task, then returns for transport to surface. The tether cable can be winched in or out of the launcher by remote control. Presently, 32 of these vehicles have been constructed and delivered.

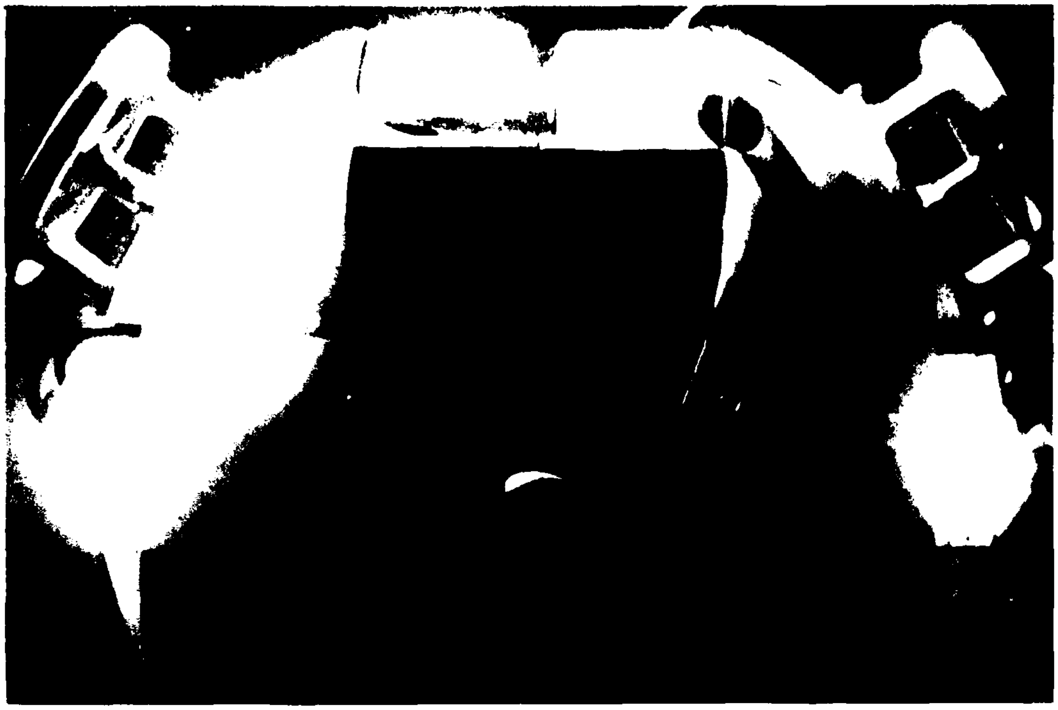


FIGURE C.9a - RCV 225
Courtesy of: Hydro Products

FIGURE C.9b - RCV 225 LAUNCH/RETRIEVAL SYSTEM AND VEHICLE IN LAUNCHER CAGE
Courtesy of: Hydro Products

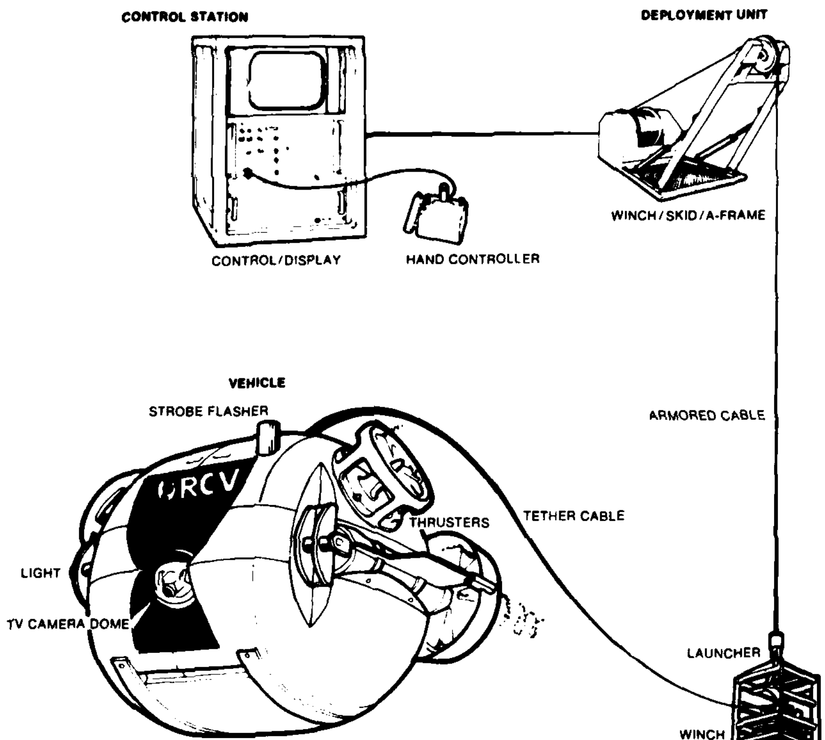


FIGURE C.9c - RCV 225 SYSTEM
Courtesy of: Hydro Products

SEA SPY

DEPTH: 1,000'
DIMENSIONS (LxWxH): 50" x 26" x 23"
WEIGHT: 225 lbs

SPEED: (Max Surface) 1.3 kts
(Max Current) 0.5 kts
STRUCTURE: Rectangular-shaped, sealed tubular Al alloy (H30) framework supports all components. Two flotation cylinders are mounted on top of frame and provide slight positive buoyancy.

PROPULSION: Four 1/5 hp induction motors drive thrusters (2 long, 1 lat, 1 vert).

INSTRUMENTATION: CCTV camera and 250W thallium iodide light, compass, depthometer, transponder.

POWER REQ: 240VAC, 1Ø, 3KW max.

SHIPBOARD COMPONENTS: Control console (18" x 9" x 6") with ground fault protection unit, separate CCTV monitor and video recorder.

SUPPORT VESSEL REQ: Cabin space for control console and video monitor, power source, deck space for vehicle, umbilical handling, launch/retrieval device.

CREW: 3-4
TOTAL SHIPPING VOL: 17 cu ft

TOTAL SHIPPING WEIGHT: 600 lbs including umbilical and spare parts.

BUILDER: Underwater and Marine Equipment Ltd., Farnborough, Hampshire, England

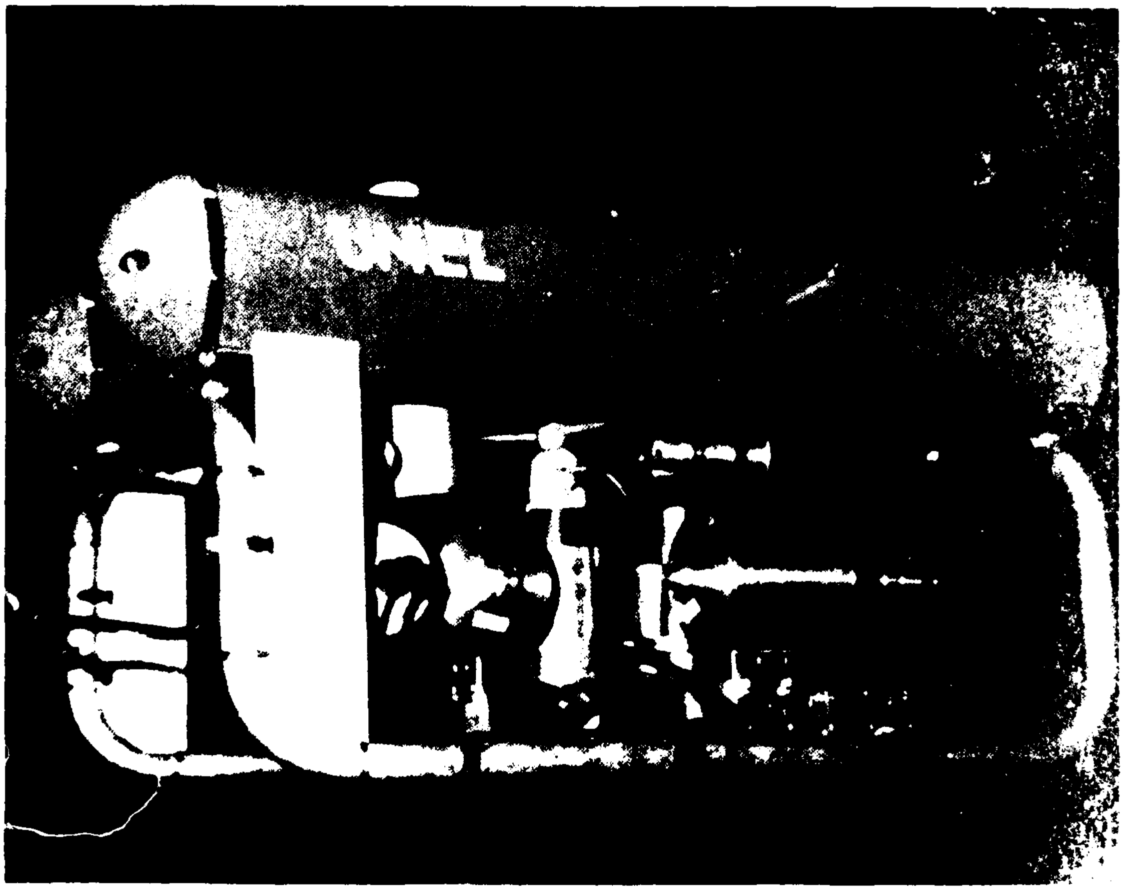


FIGURE C.10 - SEA SPY
Courtesy of: Underwater and Marine Equipment Ltd.

SMARTIE
(Submarine Automatic Remote Television Inspection Equipment)

DEPTH: 984'
DIMENSIONS (LxWxH): Approx 31" diameter x 19" high
WEIGHT: 181 lbs

SPEED: (Max Surface) NA
(Max Current) NA
STRUCTURE: Elliptical-shaped fiberglass fairing, free flooding, and enclosing all components. Vehicle has neutral buoyancy which is adjustable with leadshot ballast.

PROPULSION: A three-phase centrifugal pump pressurizing a central manifold, feeding six water jet nozzles with on-board computer-controlled butterfly valves to give thrust yaw, heave, and sway control.

INSTRUMENTATION: Three CCTV cameras, pressure transducer, mag compass, gyro compass, on-board microcomputer which can project an artificial target on the video screen, based on input from gyro and mag compass, for zero visibility maneuvering, automatic "hold" (position or course and speed) function.

POWER REQ: 440VAC, 50Hz, 3Ø

SHIPBOARD COMPONENTS: Control console, winch, cable, power supply, and launch/retrieval device.

SUPPORT VESSEL REQ: Cabin space for control console and operator, launch/retrieval device.

CREW: 3-5 depending on mission duration.
TOTAL SHIPPING VOL: NA

TOTAL SHIPPING WEIGHT: NA

BUILDER: Marine Unit Technology Ltd., 3 Friars Lane, Richmond, Surrey TW9 INL, England
COMMENTS: Vehicle is deployed in an underwater launcher from which it flies out on a 5mm diameter tether cable to conduct inspections. Launcher consists of open frame garage, motorized tether cable winch, TV camera, and light. Three vehicles have been constructed and are available for charter.

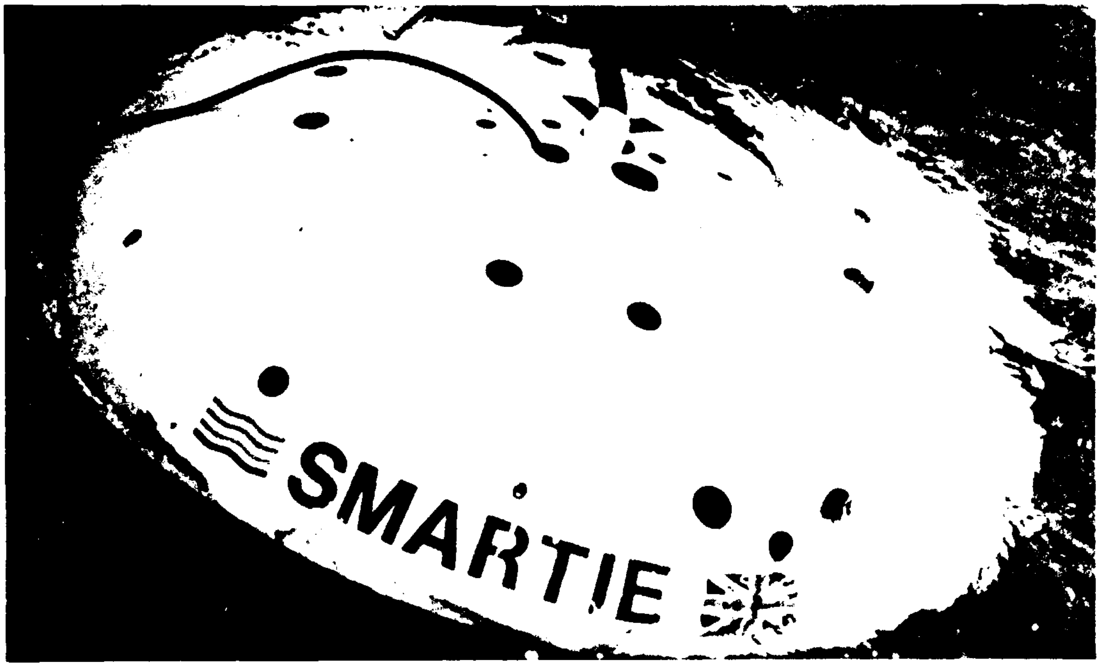


FIGURE C.11a - SMARTIE
Courtesy of: Marine Unit Technology Ltd.

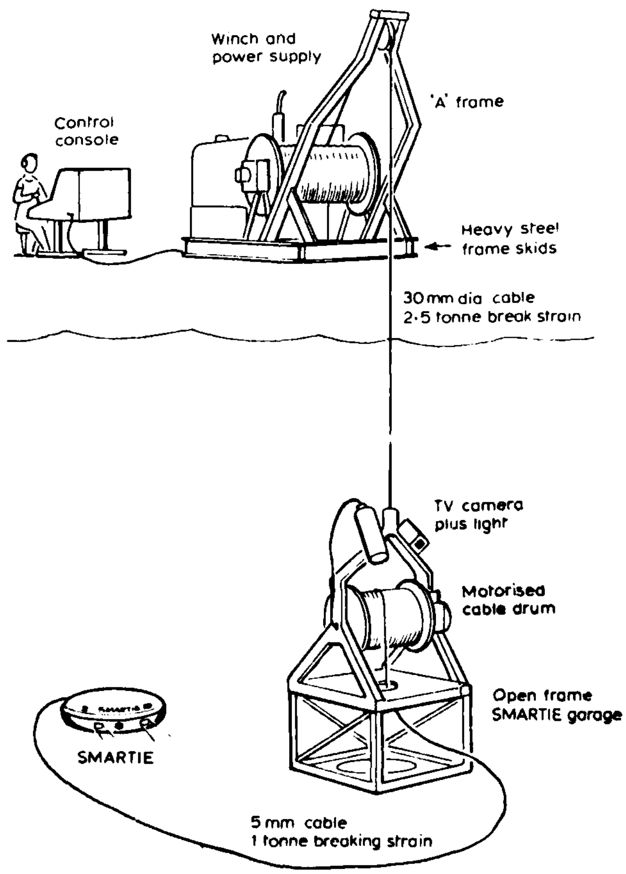


FIGURE C.11b - SMARTIE SYSTEM
Courtesy of: Marine Unit Technology Ltd.

ELECTRIC SNOOPY
(El Snoop)

DEPTH: 1,500'
DIMENSIONS (LxWxH): 40" x 26" x 18"
WEIGHT: 150 lbs

SPEED: (Max Surface) 1 kt
(Max Current) Approx 1 kt

STRUCTURE: Open tubular Al framework supports all components. Syntactic foam flotation provides slight positive buoyancy and is mounted atop the frame. Two cylindrical, pressure-resistant Al housings protect electronic components. Trim adjustable with lead ballast.

PROPULSION: Three oil-filled pressure compensated DC motors, each driving a 9" diameter, 3-blade propeller (2 long, 1 vert) with 11.5" pitch. All motors are fixed, reversible, with continuously variable speed control.

INSTRUMENTATION: CCTV camera with quartz iodide light, super 8mm cine camera, mag compass, depthometer, can be equipped with pinger and flasher. Can attach messenger line.

POWER REQ: 115VAC, 60Hz, 2.5KW

SHIPBOARD COMPONENTS: Control console, cable storage bin.

SUPPORT VESSEL REQ: Small boat davit or winch, 5' x 8' deck space, station-keeping ability is desirable.

CREW: 2
TOTAL SHIPPING VOL: Approx 100 cu ft

TOTAL SHIPPING WEIGHT: 1,200 lbs

BUILDER: Naval Ocean Systems Center, San Diego, CA 92152

COMMENTS: Vehicle is designed to provide a maneuverable real-time remote viewing capability for inspection and surveillance.

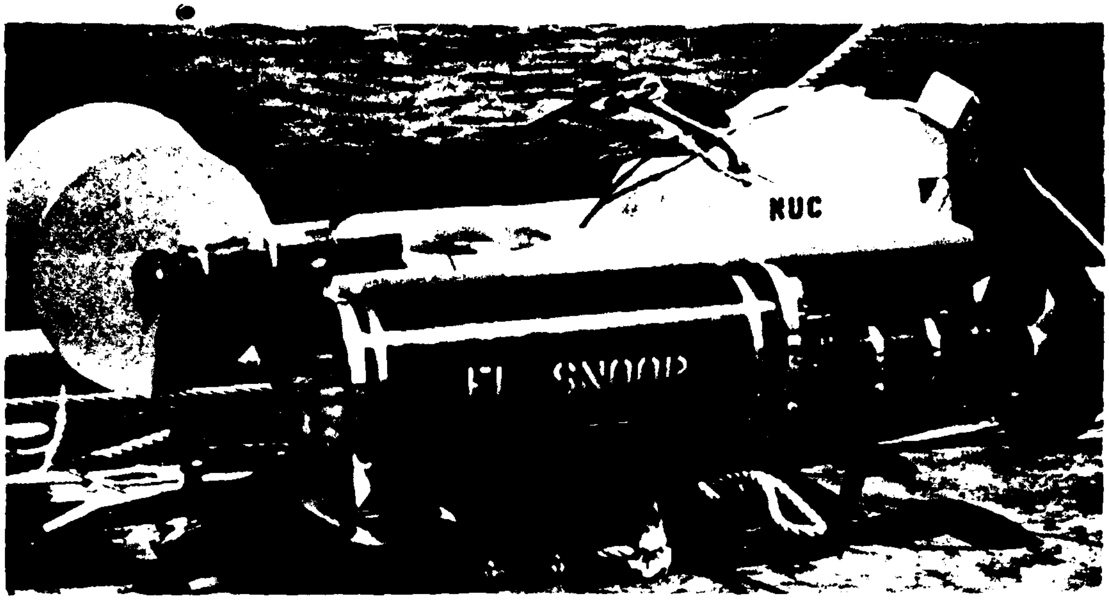


FIGURE C.12a - ELECTRIC SNOOPY
Courtesy of: Naval Ocean Systems Center

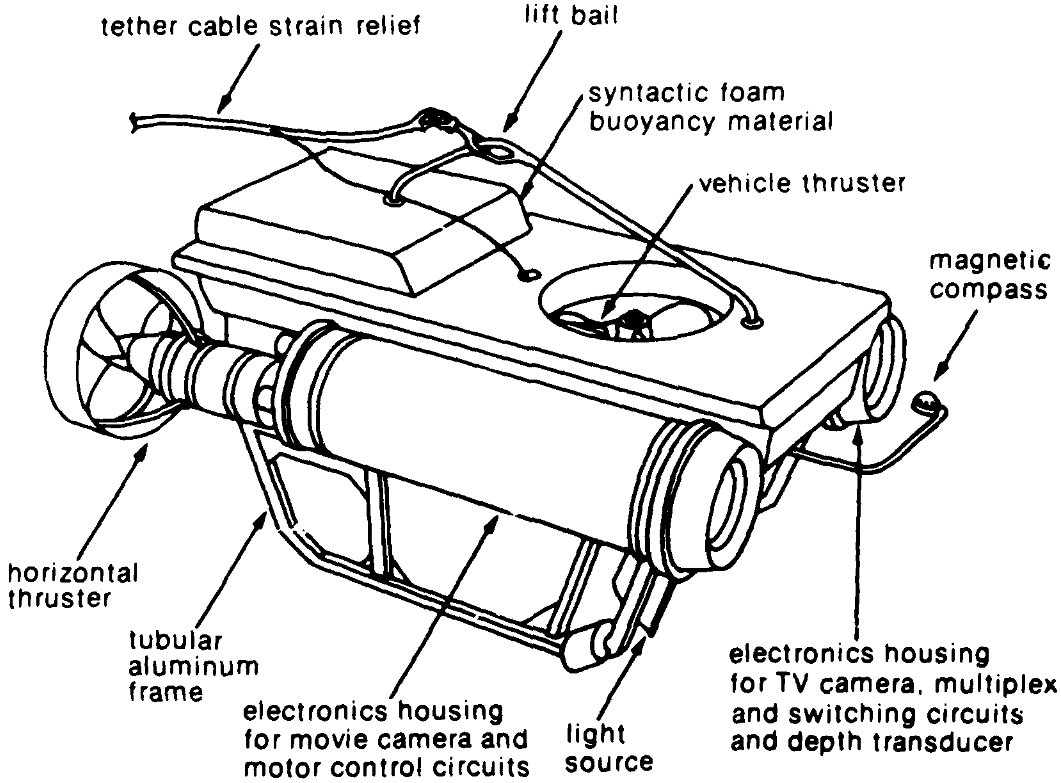


FIGURE C.12b - ELECTRIC SNOOPY VEHICLE COMPONENTS
Courtesy of: Naval Ocean Systems Center

SNOOPY (NAVFAC)

DEPTH: 1,500'
DIMENSIONS (LxWxH): 46" x 28" x 30"
WEIGHT: 475 lbs

SPEED: (Max Surface) 2 kts
(Max Current) 1.5 kts @ max depth

STRUCTURE: Open tubular Al framework supports all components. Syntactic foam attached to top of frame provides slight positive buoyancy. Two pressure-resistant Al cylinders house electronics. Trim adjustable with lead ballast.

PROPULSION: Four servo-controlled hydraulic thrusters (2 long, 1 lat, 1 vert). All are fixed and reversible.

INSTRUMENTATION: CCTV camera (low light), 250W quartz iodide light, super 8mm cine camera, mag compass, altimeter, depthometer, passive-active CTFM sonar, automatic depth/altitude function.

POWER REQ: 115VAC, 60Hz, 2.5KW

SHIPBOARD COMPONENTS: Control console, power converter box, power booster box, cable bin.

SUPPORT VESSEL REQ: Handling crane, protected space for control console, stationkeeping.

CREW: 2
TOTAL SHIPPING VOL: 111 cu ft in five containers

TOTAL SHIPPING WEIGHT: 1,370 lbs

BUILDER: Naval Ocean Systems Center, San Diego, CA 92152

COMMENTS: Vehicle was designed and built for use by Naval Facilities Engineering Command. Its next generation from Electric Snoopy with higher thrust, additional sensors and better maneuverability and control. It can be used for bottom site surveys, surveillance and documentation of diver operations, general inspection and observation tasks, implantation of seafloor markers, and object recovery.

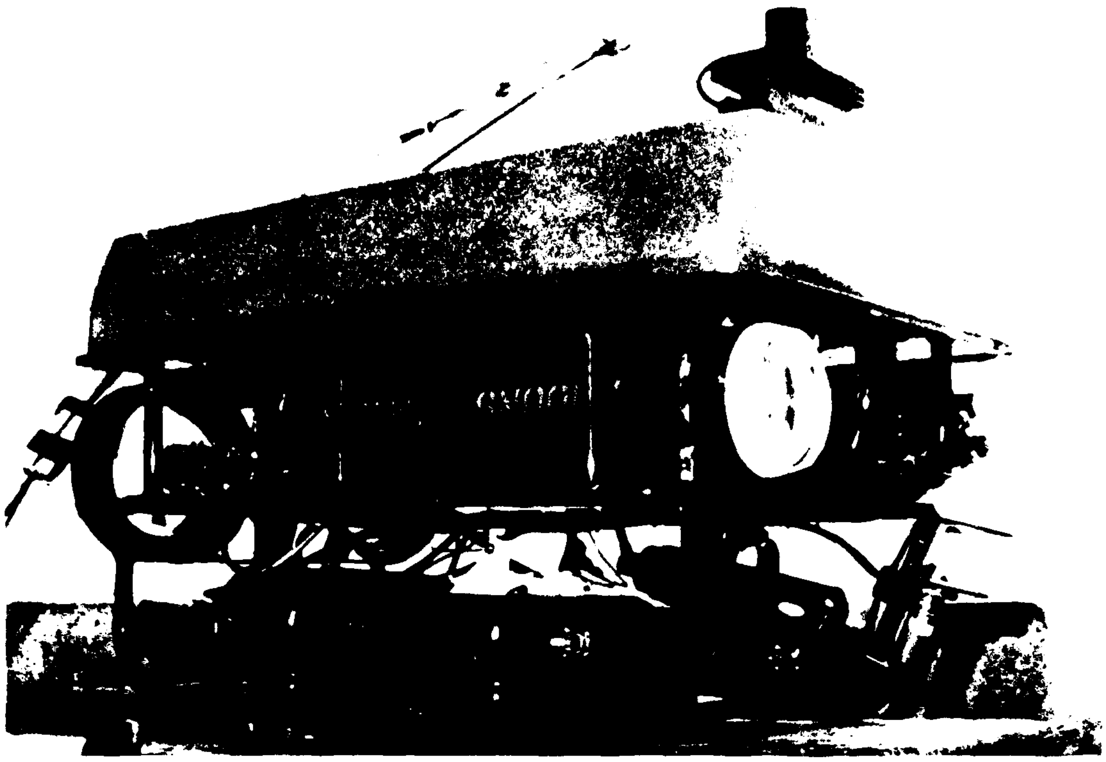


FIGURE C.13a - NAVFAC SNOOPY
Courtesy of: U.S. Navy

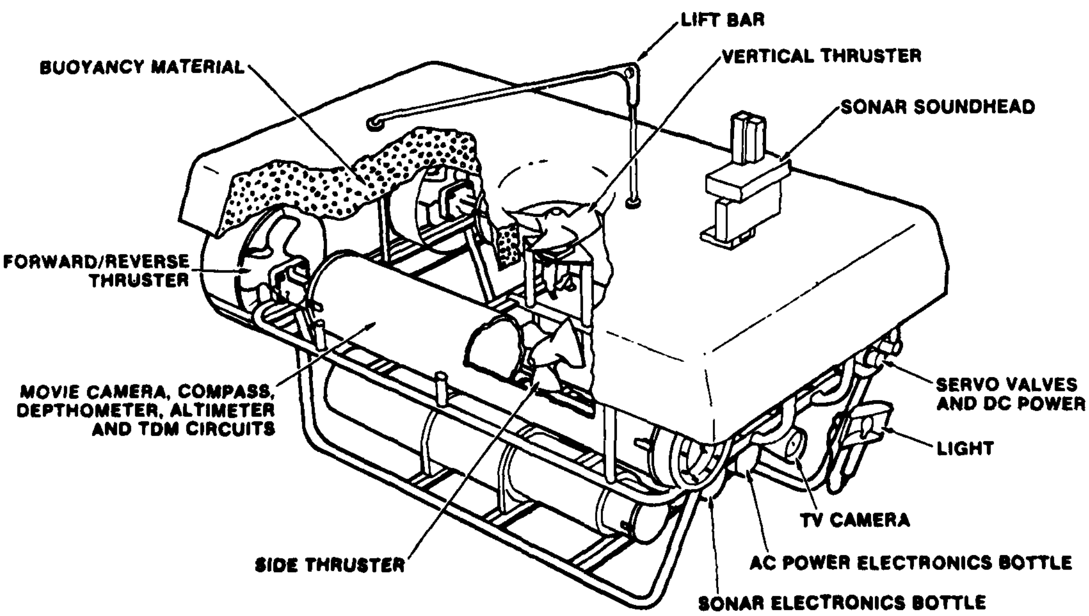


FIGURE C.13b - NAVFAC SNOOPY VEHICLE COMPONENTS
Courtesy of: U.S. Navy

SHIP HUSBANDRY VEHICLES

SCAMP

DEPTH: Equivalent to deepest draft tanker vessels
DIMENSIONS (LxWxH): 72" diameter x 20" high
WEIGHT: 1,500 lbs

SPEED: (Max Surface) 0.5 kts
(Max Current) NA
STRUCTURE: 20" high cylindrical-shaped vehicle with a fiberglass canopy donut and central impeller. Vehicle moves along hull on three wheels between which are three rotating brushes for cleaning. Styrofoam in the canopy provides buoyancy.

PROPULSION: Hydraulically driven motor drives three traction wheels; vertical impeller holds vehicle against hull.

INSTRUMENTATION: The machine can be operated either remotely or by a diver, and functions include advance, stop, or reverse, or it will automatically maintain a horizontal path on a vertical surface, lights, no CCTV.

POWER REQ: 15 hp generator powers a submersible electric motor which drives hydraulic pump. Pump in turn drives the impeller and wheels.

SHIPBOARD COMPONENTS: Control console, generator, handling device.

SUPPORT VESSEL REQ: NA

CREW: 2 minimum for vehicle
TOTAL SHIPPING VOL: NA

TOTAL SHIPPING WEIGHT: NA

BUILDER: Winn Technology Ltd., Kilbrittain, County Cork, Ireland
OPERATOR: Butterworth Systems Inc., Florham Park, NJ

SCAN

DEPTH: 328'
DIMENSIONS (LxWxH): 24" diameter x 14" high
WEIGHT: NA

SPEED: (Max Surface) 1 kt
(Max Current) NA
STRUCTURE: Cylindrical-shaped vehicle with fiberglass fairing that houses and supports all components. Plastic spheres within fairing provide buoyancy, along with an air-blown ballast tank to hold vehicle against hull.

PROPULSION: Two hydrallically driven traction wheels propel vehicle on the hull surface.

INSTRUMENTATION: Two CCTV cameras on p&t unit (one for close viewing, and a low light level camera for distance viewing), 35mm still camera, distance-travelled sensing unit. Acoustic positioning unit can be supplied.

POWER REQ: 420V, 50Hz, 3Ø, 7KVA diesel generator supplies AC power. 12V battery supplies DC power.

SHIPBOARD COMPONENTS: Control console, generator, handling device.

SUPPORT VESSEL REQ: Space for vehicle and control console with operator.

CREW: 1
TOTAL SHIPPING VOL: NA

TOTAL SHIPPING WEIGHT: NA

BUILDER: Underwater Maintenance Co. Ltd., Southampton, England

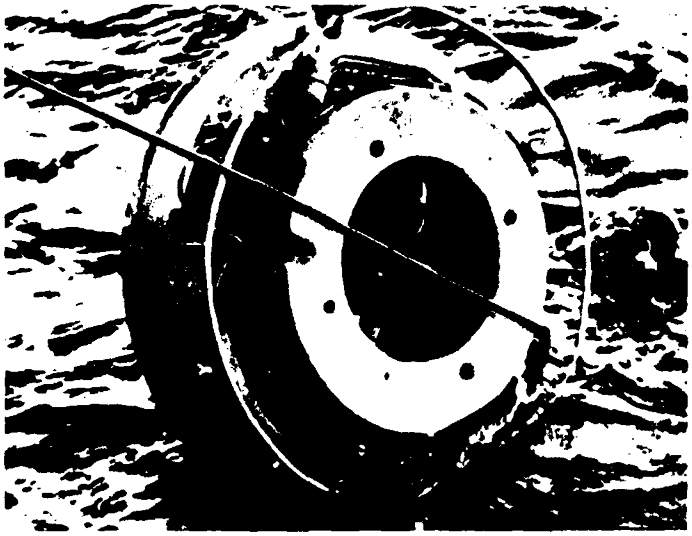


FIGURE C.14 - SCAMP
Courtesy of Butterworth Systems Inc.

FIGURE C.15a - SCAN
Courtesy of: Underwater Maintenance Company Ltd.

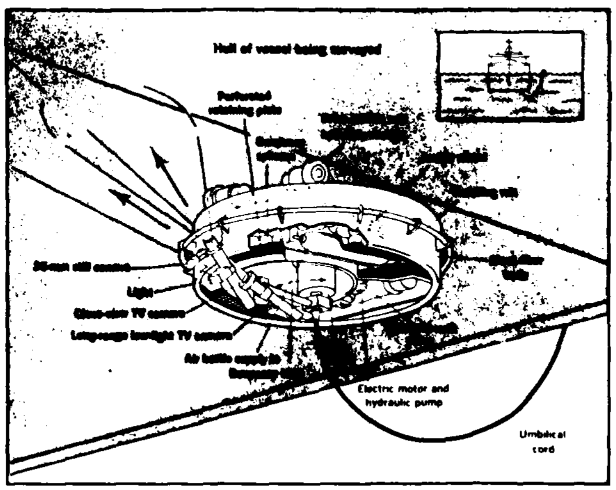


FIGURE C.15b - SCAN IN SURVEY MODE