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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

REPORT NO. CG-D-42-78

# MORPHOLOGICAL ANALYSIS
# OF
# UNDERWATER SENSING
# FOR
# COAST GUARD APPLICATIONS





APRIL 1978

FINAL REPORT

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**PREPARED FOR**

**U.S. DEPARTMENT OF TRANSPORTATION**

**UNITED STATES COAST GUARD**

**OFFICE OF RESEARCH AND DEVELOPMENT**

**WASHINGTON, D.C. 20590**

## NOTICE

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16. Abstract


The purpose of this study was to survey and explore concepts of underwater and water-related sensing systems and determine the technology appropriate for present and anticipated Coast Guard activities. The procedure employed both a literature study and a survey letter to sensor manufacturers and users to obtain a broad base of representative sensor information. The information was cataloged in a computer file using a classification system which included sensor, environment, and object descriptor groups. Selected Coast Guard activities were considered in detail to determine their general sensor requirements. A computer-aided morphological method was used to analyze the required general sensor operating characteristics and concurrently examine the data base to determine the relevance of existing technology. General recommendations were developed for the application of existing technology and for the development of new technology where indicated.


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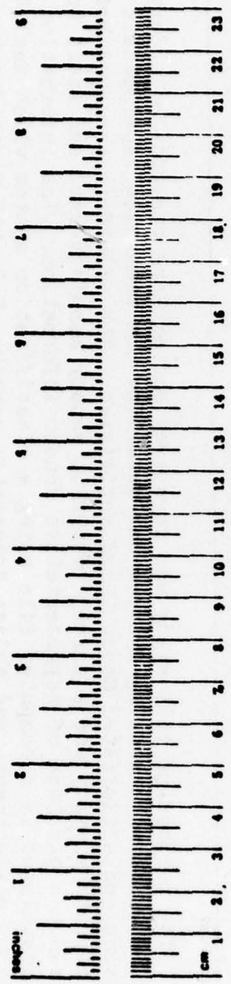
# METRIC CONVERSION FACTORS

## Approximate Conversions to Metric Measures

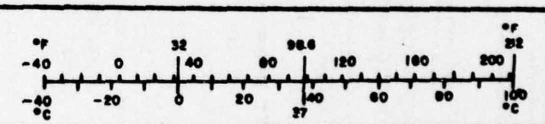
| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | *2.5 | centimeters | cm |
| ft | feet | 30 | centimeters | cm |
| yd | yards | 0.9 | meters | m |
| mi | miles | 1.6 | kilometers | km |
| | | **AREA** | | |
| $in^2$ | square inches | 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 | $yd^3$ |
| | | **TEMPERATURE (exact)** | | |
| °C | Celsius temperature | 9/5 (then add 32) | Fahrenheit temperature | °F |



## ACKNOWLEDGEMENT

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# EXECUTIVE SUMMARY

The purpose of this study was to survey and explore concepts of underwater and water-related sensing systems and determine the technology appropriate for present and anticipated Coast Guard activities. Guidelines for establishing the technical bounds of the study were developed by considering the traditional and the probable future activities of the Coast Guard. Since many of these activities require sensing of underwater as well as water surface parameters, both underwater sensing systems and sensing systems operating above the water, but directed at sensing of water surface phenomena, were included in this study.

An examination was made of the various forms of sensing energy appropriate for water-related applications. The sensitivity and effective range of potentially useful sensing systems were compared. As expected, acoustic sensors are the obvious choice for many underwater applications; but optical, electromagnetic, electrical, magnetic and chemical sensor systems are useful for specialized missions.

A data base was acquired containing information on current and developmental sensor systems relevant to the selected water-related technical areas. The procedure employed both a literature study and a survey letter to sensor manufacturers and users to obtain a broad base of representative sensor information. The information was cataloged in a computer file using a classification system which included sensor, environment, and object descriptor groups.

Selected Coast Guard activities were considered in detail to determine their general sensor requirements. An analysis

technique was developed which systematically reviewed specific Coast Guard mission scenarios to determine if they would benefit from the use of new or improved sensor systems. A computer-aided morphological method* was used to analyze the required general sensor operating characteristics and concurrently examine the data base to determine the relevance of existing technology. The output of the computer program identified sensor systems in the data base which best matched the specific mission requirements. Any set of input requirements for which the program did not produce a sensor system output thus identified a potential technological "gap". These gaps were examined to see if they were real or possibly the result of an omission of sensor information in the data base.

General recommendations were developed for the application of existing technology and for the development of new technology where indicated. These recommendations are directed at the following six major Coast Guard activities:

- Search and Rescue

The growth in satellite-communication technology should be utilized to improve emergency beacon effectiveness both for small craft and for isolated personnel distress situations. Acoustic and radio systems capable of relaying a distress signal through the air-water interface are required to aid distressed submersibles and divers.

- Oil Spill Detection and Classification

The oil-spill detection sensitivity of satellite sensors must be improved and the data transmission rates increased to obtain timely input to classification and clean-up teams.

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*A technique for methodically describing all possible ways of achieving a specified purpose.

Real-time spill detection and classification techniques using airborne sensors would provide greatly improved clean-up response times and help to minimize the area affected by spills.

- **Offshore Law Enforcement**

Present sensing systems used for offshore law enforcement are directed against surface vessels. For this purpose, improved satellite imagery and high altitude synthetic aperture radar development will be useful. However, it may soon be economically feasible to employ submersibles for illegal acquisition and transportation of high-value cargo. Improved magnetic and acoustic detectors are required to sense small submersibles at operationally useful ranges.

- **Ice Operations**

Icebreaker operations can be aided by a remote sensor system capable of determining ice properties at some distance from the vessel itself. This can be done by instrumenting a helicopter or by developing a remotely-controlled underwater vehicle with upward looking sonar. Data on ice coverage in remote areas can be obtained using improved sensors on new satellites such as SEASAT-A. Data relay via satellite from local sensors can provide quantitative information on ice thickness in remote regions.

- **Port Safety and Security**

Water-based terrorist or sabotage activity is a potential threat in port areas handling valuable or dangerous cargo. Incursion by swimmers or small vessels (surface or submerged) may be detected by acoustic and magnetic barrier systems set along harbor entrances or pierheads. Bistatic (shadow-detecting) acoustic sensors should be further developed for this purpose.

• **Underwater Aids to Navigation**

Underwater acoustic beacons, transponders, and reflectors will be increasingly useful for commercial submersible operations. However, the increased use of submersibles, acoustic navigation systems, and other underwater acoustic sensors, will soon require frequency channel allocation to minimize interference, as has long been the case in the electromagnetic spectrum. This may well come under the authority of the Coast Guard for regulation and enforcement.

Because of the broad scope required, this study did not consider detailed questions of engineering requirements and cost-effectiveness for the various sensor configurations suggested by the analysis process. Those configurations which are technically realizable and of practical interest to the Coast Guard, such as the examples discussed above, are recommended for further consideration. Thus, a Coast Guard review is appropriate at this point to select the principle sensor candidates for concept development and cost-benefit analysis.

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# 1. INTRODUCTION

The Coast Guard is presently building a technological base for future underwater capabilities. This requires systematic investigation of many aspects of the underwater environment. Coast Guard programs in Aids to Navigation, Port Safety and Security, Commercial Vessel Safety, Marine Environmental Protection, and Search and Rescue can all benefit from advances in underwater technology. The Coast Guard presently has a substantial capability for performance of these missions, but future demands will require development and use of advanced technology. Ocean exploration and exploitation efforts are growing rapidly. Expected legislation could increase Coast Guard underwater responsibilities to include functions such as inspection of offshore structures and protection of coastal and offshore assets. Future developments such large submarine commercial carriers, automated submersibles, underwater habitats, and offshore power plants will require new types of underwater sensing systems to be used by the Coast Guard.

The objective of this study was "to survey and to explore the concepts of underwater sensing devices and systems, and to determine the technology required to allow the Coast Guard to meet possible needs in the area of underwater sensing for the next 5 – 25 years."

The sensor technologies to be studied were determined by examining Coast Guard operations in the program areas discussed above. A computer-aided morphological analysis was conducted in selected program areas to determine if Coast Guard needs are being met with present technology or if new technology must be developed. Specific recommendations have been made where present technology seems deficient.

The procedure used in the study involved the following tasks:

*Task 1.* Determine in detail the sensor technology to be studied based on an examination of present and possible future Coast Guard activities.

*Task 2.* Review current literature and contact manufacturers, government laboratories, and private research institutions to determine the present state of the art and obtain information on developing technologies.

*Task 3.* Design a taxonomy for sensor-system classification and computer-aided cataloging of the sensor information obtained from Task 2.

*Task 4.* Analyze the present and possible future Coast Guard uses of sensor systems by examining mission scenarios and determining where appropriate sensor systems would be beneficial. Use a computer-aided morphological method based on the sensor taxonomy to catalog all sensor system combinations of relevance, and determine if suitable examples exist in the data base.

*Task 5.* Using the results of the morphological analysis, identify the classes of sensor systems having the best potential benefit in Coast Guard applications. Determine if existing sensors will provide the required performance or if modification of present technology or development of new technology is needed.

The results of these tasks are presented in the following sections of this report.

## 2. THE FUNCTION OF SENSOR SYSTEMS IN PRESENT AND FUTURE COAST GUARD MISSIONS

The guidelines for establishing the technical bounds of the study were developed by considering both the traditional and the probable future activities of the Coast Guard. The present Coast Guard budget was examined to learn present mission priorities in terms of how operating and R&D funds are spent. The Coast Guard Program Standards were reviewed for information about present and near-term operating requirements. Finally, the Commandant's Long Range View[1] was used to provide information about the anticipated mission requirements in the next 5 – 25 year period.

Based on the review of these documents, a group of appropriate Coast Guard activities was selected to serve as a focal point for the study. The set of sensor technical areas for the literature review and current information search was determined by developing specific mission scenarios within each of the general activity descriptions in the Coast Guard Documents. This process is illustrated in Table 2.1.

After examining the information in Table 2.1, it was apparent that many of the Coast Guard activities involved the sensing of both underwater and surface phenomena. Pollution detection, for example, may involve sensing pollutants on the surface as well as in the water column. Search and rescue of submersibles involves the probable requirement of transmission of information through the air-water interface. Ice

[1]U.S. Coast Guard, Commandant Instruction 5000.2B, 18 July 1977.

thickness measurement may involve the coordination of data from both underwater and in-air sensors. To avoid excluding sensor systems of Coast Guard interest, the scope of the study was expanded somewhat to include sensor systems generally used above water, which were involved with sensing water-related parameters.

Since the objective of this study was thus expanded in scope to cover a broad range of underwater and water-related sensors, it was necessary to establish some ground rules to provide reasonable bounds to the types of technology to be included. Hence after reviewing the information summarized in Table 2.1, it was decided that several classes of marine sensor systems would not be included in this study. Examples of these sensor systems and the reasons for exclusion are

Radar systems used for navigation and collision avoidance (Properly the subject of a separate study)

Military sonar systems used for long range submarine detection and antisubmarine defense (Not applicable for peacetime Coast Guard missions)

Radio and electronic navigation systems such as Loran C, DECCA, OMEGA, etc. (Properly the subject of a separate study)

Sensors for surface acoustic and visual navaid systems such as fog detectors, light-operated switches, etc. (These devices are considered to have only in-air applications.)

TABLE 2.1. UNDERWATER AND WATER-RELATED SENSOR TECHNOLOGY APPROPRIATE FOR PRESENT AND FUTURE COAST GUARD ACTIVITIES

| Present Activity | Long Range View Input | Relevant Water-Related Sensor Technologies |
|---|---|---|
| Search and Rescue<br>Respond to marine and aircraft accidents, floods and ice conditions | • All-weather operation<br>• Ice Area Operations<br>• Submersible search and rescue<br>• Under-ice (submersible) search and rescue<br>• Satellite-aided search and rescue | • Electromagnetic, optical and acoustic detection, surveillance, communication and navigation systems<br>• Systems for transmission of information through the water-air interface<br>• Underwater detection, location and navigation systems |
| Aids to Navigation<br>Maintain network of manned and unmanned aids along coast and waterways. Include visual, audible and electronic signals | • Improve effectiveness and reliability of aids while reducing operating and maintenance costs<br>• Improve buoy positioning technique<br>• Improve electronic aids (Loran-C)<br>• Augment Loran-C to provide ship positioning information in harbor areas<br>• Improve navaid reliability in ice covered areas | • Underwater navaid technology is of primary interest<br>• Acoustic beacons, transportation and positioning systems relevant to ice-covered area navigation and to submersible navigation<br>• Electromagnetic and magnetic sensors may be relevant for short-range guidance systems |
| Marine Safety<br>• Insure compliance with Federal regulations by ships and personnel<br>• Recreational boating safety | • Offshore structure safety<br>• Cargo handling safety on new types of ship | • Mechanical parameter sensing on offshore structures<br>• Systems for monitoring ship hull integrity |
| Marine Environmental Protection<br>• Prevention of damage to marine environment<br>• Inspection of vessels and waterfront activities<br>• Conducting of pollution patrols<br>• Port operations safety<br>• Harbor traffic control | • Detection and response to small spills in coastal waters<br>• Capability to deal with massive spills<br>• Identification of oil origin<br>• Deepwater port regulation<br>• Port security from sabotage and terrorism | • Remote optical and electromagnetic sensing of oil spills<br>• Oil spill classification sensors<br>• Acoustic ship movement sensors<br>• Detection and Surveillance systems for port safety |
| Ocean Operations<br>• Offshore law enforcement<br>• Ice patrol, ice-breaking operations<br>• Marine science activities | • 200-m fishing zone enforcement<br>• Satellite detection and identification<br>• Fast response vessels<br>• LTA craft<br>• High seas crime, piracy and drug traffic control<br>• Offshore mining activities | • Acoustic, electromagnetic, and optical surveillance systems<br>• Ice measurement and mapping sensors<br>• Sensors for long range detection of small craft, doppler radars and sonars |

## 2.1 An Overview of Relevant Sensor Technology

Sensors are devices for transferring information which is usually contained in a stimulus or sensing energy. The most effective sensing systems are those where the sensing energy is compatible with the properties of the propagating medium used for transmitting the stimulus information. Thus electromagnetic signals are the most commonly employed sensor stimuli in air or space both of which are insulating media. In seawater, electromagnetic waves are not very useful since they are highly attenuated (except at very low frequencies) by the conductive properties of the water. However, the density and low compressibility of water make it a much better acoustic medium than air. Thus sound is a very effective underwater sensor stimulus. Light which is also very useful for sensing in air or space, is only useful in clear ocean water because of the attenuation due to scattering from suspended particles and due to absorption by the water. Many other sensing stimuli such as magnetic and electric fields, radioactive phenomena, and chemical agents may be useful for short-range applications, but they generally do not have the information carrying ability of rapidly controllable signals.

In this section, a comparison of the effective underwater range of various sensing systems is presented. This comparison is based on a study by the Naval Undersea Research and Development Center (NUC)[2] which examined the underwater use of static electric and magnetic fields, radioactive fields, chemical systems, extremely low frequency (ELF) electromagnetic radiation,

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[2]A. Gordon, ed., "Undersea Detection of Various Signals," Naval Undersea Research and Development Center, San Diego, Report NUC TP 294, July 1972.

light, and acoustics. (The technical detail in the balance of Sec. 2 is supplementary and may be omitted if not of direct interest to the reader.)

### 2.1.1 Electric and magnetic fields

Electric field detection may be used to determine the location of a submerged object undergoing electrolytic decomposition. The range obtainable is on the order of the dimensions of the object itself. A more effective use of electric field effects is obtained by setting up a spaced set of submerged electrodes or antennae and applying a voltage across them to produce a conduction current field. The effective range of this field is determined by the geometry of the electrodes and the applied electrical power. Table 2.2 shows the theoretical range of an electric dipole as a function of input power. The dipole in this example was formed by 2 spheres of 0.1 m radius spaced $2\pi$ m apart. The receiving potential is measured across the ends of a $2\pi$ m antenna. The electrical noise limits of this type of sensor are generally determined by the interaction of water motion (current or turbulence) with the earth's magnetic field. The noise limit determining the range shown in Table 2.2 was produced by an assumed water current of 0.1 cm/sec.

Magnetic field technology has recently been advanced by the development of superconducting magnets and field sensors. Magnetic anomaly detection (MAD) equipment is widely used for submarine detection. In most MAD applications, a local variation in the earth's magnetic field is sensed to obtain the required information (detection). If a magnetic source such as an electromagnet were used, its high local magnetic field produces an anomaly in the earth's field which is detectable

TABLE 2.2. STATIC ELECTRIC AND MAGNETIC FIELDS (From Ref. 2)

| Source | Dimensions | Weight | Power or Magnetization (P or M) | Range (R) |
|---|---|---|---|---|
| Static Magnetic Field | | | | |
| Copper torus | $r_1 = 1.0$ m<br>$r_2 = 10^{-1}$ m | 2 tons | P = 10 W<br>$M = 5.44 \times 10^3$ A-$m^2$ | 30 m |
| Permanent magnet | Length >> width<br>Volume = 0.25 $m^3$ | 2 tons | $M = 2.61 \times 10^5$ A-$m^2$ | 130 m |
| Filled solenoid | Length = $2\pi$ m<br>Diameter = 0.2 m | 3.8 tons | $M = 3.2 \times 10^5$ A-$m^2$<br>P = 70 W | 135 m |
| Superconducting coil | $r_1 = 1.0$ m | -- | $M = 3.56 \times 10^6$ A-$m^2$ | 320 m |
| Static Electric Field | | | | |
| Electric dipole | Length = $2\pi$ m<br>$r_s = 0.1$ m | -- | P = 10 W | 160 m |

at an appreciable distance. Table 2.2 also shows the effective range of this type of device as a function of the magnetic moment of the transmitting field. The noise limit in this case is determined by small local magnetic anomalies superimposed on the earth's field. Note that an electromagnet with a 10 W input can be detected at about 30 m compared with about 160 m for the 10 W electric dipole.

The effective noise limit of magnetometers can be improved by using them in pairs connected as a gradiometer. In this application, the noise due to the earth's large-scale field variations is effectively equal in both sensors. Thus when their outputs are connected in opposition, the earth's field component is cancelled and only short spatial magnetic fluctuations due to local anomalies are detected. Unfortunately, these local natural anomalies often have characteristics similar to the object or magnetic source being searched for.

### 2.1.2 Radioactive fields and chemical systems

The range of most nuclear radiation in water is quite limited. Gamma rays and neutrons have the most penetrating power for conveniently detectable nuclear radiation. The gamma rays from a 100 Curie point source of Cobalt-60 would be attenuated to background level about 10 ft from the source[2] Neutrons from a $10^{11}$ n/sec source would be detectable out to about 8 ft.[2]

Neutrinos are able to pass readily through water (and most matter) and would be very useful for long-range sensing. However, they are detected only with difficulty because of their low interaction with matter, and no technology exists for modulating their emission rate to convey information.

The radioactivity induced in seawater by a neutron source is carried from the vicinity of the source by the normal diffusion of the water. This activity generally would be sufficiently above the background level to be detected 1 mile from a $10^{11}$ n/sec source when carried by a 1 kt current.[2] In this application however, no additional benefits, and some considerable hazards, are obtained over a chemical diffusion type of source.

Several forms of *in situ* chemical sensors have been developed for measuring water pollutant concentrations. These sensors can be employed to sense a chemical marker agent used for a locating beacon or for tracing current profiles.

Chemical agents used must not be present in normal seawater and must be detectable in concentrations down to 0.1 ppb to avoid having to use inordinately large amounts of chemical.[2] The agent is diffused horizontally much more widely than vertically because of the normal horizontal stratification of the ocean.

When agents are instantly released, they spread quickly as they drift with the current. A maximum useful (detectable) patch size is reached which then begins to decrease. For example, instantaneous release of 22 kg of Rhodamine B dye resulted in a maximum patch with dimensions of 21 km length, 0.9 km width, and 8.3 m thickness. The effective time of maximum volume was 96 hr (based on a detectable concentration of 0.01 ppb).[2]

When the agents are continuously released, a steady-state patch geometry is reached which remains connected to the release point. Thus in a search mission it would only be necessary to follow the patch "upstream" to find its origin. A comparison of the cost-effectiveness of various chemical agents for a required detection range is shown in Table 2.3.

TABLE 2.3. CHEMICAL SYSTEMS (From Ref. 2)

| Type of Marker | Background | Minimum Detection Limit, $D_0$ | Release Rate, $R_0$ | Amount Required for 1000 hr of Operation | Cost of Material* | Range | Effect of Parameters on Range |
|---|---|---|---|---|---|---|---|
| Rhodamine B | <0.01 ppb | 0.01 ppb | 10 g/hr | 10 kg | $30/kg | 3 km | Range ~ $R_0/D_0$ |
| Fluorescein | <0.01 ppb | 0.01 ppb | 10 g/hr | 10 kg | $20/kg | 3 km | Range downstream decreases and range upstream increases as current velocity decreases. |
| Iodine-131 | 300 pCi/l | 30pCi/l | 0.03 Ci/hr | 30 Ci | $1200/Ci | 3 km | |
| Iron-59 | 300 pCi/l | 30pCi/l | 0.03 Ci/hr | 30 Ci | $28,000/Ci | 3 km | Total range along current axis remains approximately constant. |
| Copper ion | 0.003 ppm | 0.6 ppm | $2.4 \times 10^6$ g/hr | $2.4 \times 10$ kg† g/hr | $8/kg | 3 km | |
| Mercuric ion | 0.03 ppb | 2 ppb | 2700 g/hr | 2700 kg** | $30/kg | 3 km | |
| pH | 8.1 | ±0.1 pH | $3.7 \times 10^4$ equivalent/hr (equivalent of $H^+$ to reduce pH by 0.1 unit) | $3.7 \times 10^7$ equivalent | $0.01/equivalent | 3 km | Lateral range ~ (current velocity)$^{-1/2}$ |

*Cost for laboratory grades and quantities.
†Weight of cupric nitrate ($Cu(NO_3)_2 \cdot 3H_2O$).
**Weight of mercuric chloride ($HgCl_2$).

### 2.1.3 Extremely low frequency electromagnetic radiation

The conductive nature of seawater causes electromagnetic energy to be absorbed by charged ions. The resulting attenuation per unit distance is frequency dependent and is lowest at low frequencies. Thus only frequencies below 100 Hz have been found to be practically useful for electromagnetic propagation underwater.

When the transmitter and receiver are near the surface much of the energy is transmitted through the air and a significant improvement in range results. Similarly, when the transmission path is near the bottom, the electrical properties of the bottom often provide less attenuation than seawater and an increase in range results.

The primary noise source for electromagnetic receivers underwater is low-frequency atmospheric noise such as from lightning and power transmission lines. Since the conductivity of the seawater acts as a shield, the sensitivity of deep receivers is limited only by their own input noise. Detection range is improved by narrowband filtering and coherent detecting, however these techniques also severely restrict the achievable information rate.

Table 2.4 shows the theoretical variation of detection range vs transmission path depth for low-frequency electromagnetic signals.[2] In this table, the transmitter is assumed to have a 10 m antenna with a radiated power of 10 W. The receiver detector is assumed to have a 100 sec averaging time. The receiver is assumed to be atmospheric noise limited down to a depth of 800 m, below this the range would be determined by system noise, hence typical lower limit values are shown here.

TABLE 2.4. EXTREMELY-LOW-FREQUENCY ELECTROMAGNETIC WAVES (From Ref. 2)

| Depth, m | Frequency, Hz | $r/\delta_w$ | $r/\delta_b$ | Range, m | Remarks |
|---|---|---|---|---|---|
| 0 | 4 | 90 | | 11,300 | Surface effects included |
| 0 | 10 | 170 | | 13,600 | |
| 0 | 100 | 750 | | 19,000 | |
| 100 | 4 | 63 | | 7,900 | |
| 100 | 10 | 95 | | 7,600 | |
| 100 | 100 | 70 | | 1,700 | |
| 400 | 4 | 13.5 | | 1,700 | Infinite medium approximation |
| 400 | 10 | 17 | | 1,360 | |
| 800 | 4 | 16.3 | | 2,000 | |
| > 1300 | 4 | 19 | | 2,400 | |
| > 720 | 10 | 20 | | 1,600 | |
| > 180 | 100 | 22 | | 330 | |
| > 1300 | 4 | | 18 | 14,400 | Near bottom |
| > 720 | 10 | | 20 | 10,400 | |
| > 180 | 100 | | 21 | 3,360 | |

Notes: r - range

$\delta_w$ - attenuation length in water

$\delta_b$ - attenuation length in seabed

All data for $TP\ell = 10^4$ where

T - observation time, sec

P - transmitter input power, W

$\ell$ - antenna length, m

In general, the table shows that the greatest ranges are achieved near the surface using higher frequencies. Transmission near the bottom does almost as well, but here the lowest frequencies produce the best range. The range achieved is sensitive to the value of the bottom conductivity. At mid-depths, away from the surface and bottom effects, the lowest frequencies again produce the greatest range. The ranges achieved using 10 W low frequency EM wave transmission can be seen to be appreciably greater than the 30 m and 160 m values predicted for the 10 W static magnetic or electric field sources.

### 2.1.4 Underwater light transmission

The absorption of light energy by seawater is wavelength dependent, and is minimum in the region from 4500 to 5500 Å. Thus, to achieve the greatest transmission range, optical sources and detectors should operate in this band. Fortunately, several powerful optical sources are available such as the argon laser, the yttrium-aluminum-garnet (YAG) laser, and the thallium-iodide doped mercury arc lamp. The lasers have high beam collimation but low efficiency (0.1 to 2%) and the mercury lamp relatively high efficiency (16%) but low beam collimation. The YAG laser, at present, offers the highest beam power capability but its output at 5300 Å suffers almost twice as much attenuation per meter than does the output of the argon laser at 4765 Å.

The state of the art in optical detectors has reached the point where an individual photon is detectable. Hence, the only feasible detector improvement for achieving increased optical sensor operating range is improved signal processing to reduce noise from interfering light quanta and from detector dark current pulses. The primary sources of interfering noise for optical systems in the ocean are background illumination near the surface and bioluminescence at depth.

In order to compare the potential performance of optical sensors in the ocean against other sensors, it is useful to determine the maximum detectable range for a laser-detector system. Table 2.5 shows the values obtained[2] for the argon and YAG lasers as a function of depth in clear ocean water. The detector noise level was assumed to be controlled by daylight penetration at shallow depth, bioluminescence at intermediate depth and by the number of available photons for deep sensors (as shown in the table). For photon-limited detection, a required arrival rate of about 2 photons/sec was assumed over a 5-sec observation period.

The values shown in Table 2.5 indicate that a maximum detectable range of about 1 km is achievable for a 10 w (average output power) argon laser beam in seawater. In order to increase this range it is necessary to increase the beam power, the receiving aperture area, or the observation period. For photon limited detection, an increase of a factor of 10 in any of these quantities results in a range increase of only about 50 m for the argon laser, since the beam attenuation is controlled by absorption loss, not spreading loss. Moreover, it must be remembered that the values shown in the table are for clear ocean water, a condition that is often not found — especially near the surface.

### 2.1.5 Underwater sound transmission

Sound is widely used by underwater sensor systems since it propagates well in seawater at frequencies which permit a large

TABLE 2.5. UNDERWATER PROPAGATION OF LIGHT (From Ref. 2)

| Laser Type | Power Input | Power Output (efficiency) | Attenuation Coefficient (attenuation length) | Depth | Range (limited by) |
|---|---|---|---|---|---|
| Argon ion | $10^4$ W | 10 W (0.1 percent) | 0.039/m 26 m | 75 to 650 m | 610 to 860 m (daylight penetration) |
| Argon ion | " | " | " | 650 to 4000 m | 860 to 1030 m (biolumi-nescence) |
| Argon ion | " | " | " | >4000 m | 1030 m (photon limited) |
| Frequency-doubled YAG | 500 W | 5 W average, $5 \times 10^6$ W peak | 0.06/m 17 m | 75 to 650 m | 520 to 690 m (daylight penetration) |
| Frequency-doubled YAG | " | " | " | 650 to 2500 m | 690 to 710 m (biolumi-nescence) |
| Frequency-doubled YAG | " | " | " | >2500 m | 710 m (photon limited) |

amount of information to be carried. Underwater sound propagation is influenced by the density, salinity and thermal gradients in the ocean and thus rarely follows a straight propagation path. The propagation of sound in the ocean is a complex subject, well covered in the literature[3]. Hence, to permit a convenient comparison of sound energy propagation with the other forms of underwater sensing previously discussed, an isotropic medium is assumed where sound propagation losses are controlled by spherical spreading and an absorption factor per unit distance.

The output power available from an acoustic source is limited by the cavitation threshold of the water. This effectively limits the transmitted power to about 1 $W/cm^2$ near the surface. Thus to increase the achievable output power it is necessary to increase the radiating area of the source. However, when this is done the source becomes more directive, i.e., more like a searchlight, and special designs are required to achieve the desired radiation pattern.

Acoustic receiver sensitivity is determined by the crystal geometry and the type of piezoelectric material used. Modern hydrophone designs are generally ocean-ambient-noise-limited rather than receiver-noise-limited. Hence, improved effective sensitivity is obtained by making the hydrophone or receiver array directive to limit the amount of ambient noise received and by employing special signal processing.

The maximum achievable range for an acoustic transmitter-receiver system is shown in Table 2.6. Here the range is determined at several frequencies for a 10 W 1-sec transmitted pulse.

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[3]See, for example, R.J. Urick, *Principles of Underwater Sound for Engineering*, 2nd Ed., McGraw-Hill, N.Y., 1975.

TABLE 2.6. UNDERWATER PROPAGATION OF SOUND

| Frequency | Attn. (dB/km) | Max. Detectable Range |
|---|---|---|
| 10 kHz | .6 | 60 km |
| 32 kHz | 5.0 | 12 km |
| 100 kHz | 30 | 2.4 km |

Assumptions:
- 10 W Omnidirectional source
- S.S.2 Ambient noise (thermal noise limit at 100 kHz)
- 10 dB S/N ratio
- 1 Hz Signal bandwidth
- Omnidirectional receiver
- $16^{\circ}C$ Water temperature
- 35 ppt salinity

The receiver noise limits are determined by the ambient noise in a 1 Hz filter band for Wenz Sea State 2 spectra. A recognition differential of 10 dB has been used (signal = 3x noise level).

The observed values of achievable range can be seen to be appreciably greater than the ranges obtained at the same 10 W output power for the other forms of underwater sensing energy considered. Thus, underwater acoustic sensing systems are evidently the winners in terms of efficiency and achievable range. However, for special applications, other sensor requirements must be considered such as extremely broad bandwidth, transmission through the water-air interface, or measurement of chemical and optical phenomena. In these cases appropriate, nonacoustic, sensing means must be selected. This study will thus be broadly based and include representative sensor systems from all of the groups discussed.

# 3. MORPHOLOGICAL ANALYSIS APPLIED TO SENSOR TECHNOLOGY

## 3.1 The Morphological Method

The term "morphological method" was first used by Fritz Zwicky[4] to describe a technique for methodically describing all possible ways of achieving a specified purpose. This technique, if carefully formulated, is capable of focussing attention on possibilities for achieving the purpose which are not immediately obvious, and which may be of considerable benefit if implemented. The method is thus useful in assisting technology forecasting but must be supplemented by judgmental insight on technological feasibility.

In order to use morphological analysis productively it is essential that the fundamental aspects (principal fields) of the selected subject be identified, i.e., that its organic structure (morphology) be understood. The ways of realizing each of the fundamental components are then analyzed to derive a general taxonomy for the entire subject.

This process can be illustrated by considering the problem of making a sandwich. Table 3.1 shows a sandwich taxonomy which is representative but not all-inclusive. This taxonomy recognizes that the morphology of a sandwich has five fundamental organic component groups. To determine all possible ways of making a sandwich, it is necessary to consider all combinations of each component in the five major groups, a total of 22,680 possible morphologies. Thus, the process of morphological analysis forces one to consider every combination ranging

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[4]F. Zwicky, *Discovery, Invention and Research*, McMillan, New York, 1969.

TABLE 3.1 TAXONOMY OF A SANDWICH

1. **Bread**

   white, whole wheat, pumpernickle, rye, French bun, English muffin, bagel, long roll, onion roll

2. **Spread**

   cream cheese, butter, mayonnaise, margerine, mustard, olive oil, none

3. **Filling**

   ham, cold meats, lox, kippers, peanut butter, jam, hard cheese, process cheese, hot dogs, pastrami, hamburger, none

4. **Relish**

   lettuce, onions, sliced olives, piccalilli, none

5. **Spice**

   salt, black pepper, red pepper, tabasco, oregano, none

from the absurdly obvious to the obviously absurd. Presumably, somewhere in the middle are delectable sandwich possibilities such as a kipper and cream cheese sandwich on an onion roll with sliced olives and a dash of tabasco.

Since the routine analysis of 22,680 sandwich combinations would require an appreciable effort, even if only theoretical, it is useful to reduce the number of combinations to involve only the essential fields of the taxonomy. Thus, for sandwiches, the essentials are probably bread, spread, and filling. The remaining total combinations are thus reduced to 756, which represents a more easily digested analysis task. If additional privation can be endured, a morphological analysis can be done considering only the bread and filling taxonomy fields. This results in 108 "residual" morphologic combinations which consider only the major nutritional components of a sandwich.

This process of reducing a complete taxonomy to a simpler one containing only the most essential components is thus the key to developing useful (and manageable) morphological analysis procedures for complex systems.

## 3.2 Development of a Sensor Taxonomy

The process of developing a taxonomy for water-related and underwater sensors was difficult because it was not an easily conceptualized, isolated technology such as sandwich making. Many technical fields were involved as well as many different sensing requirements. Thus to insure that an adequate taxonomy was obtained, three major groups of descriptor fields were included. These were derived by considering the primary function and major working principles of the sensor itself, the environmental relationship between the sensor and the object sensed, and information about the object and its interaction with the sensing process. This is a variation on the classic "source" — "path" — "receiver" concept used in acoustics and other information transfer technologies.

Sensor descriptors were selected which are based on scientific sensing principles rather than on terms more specific to sensor operation. This was done so the taxonomy would remain relevant even though sensor types were added, modified, or dropped. The various forms of sensing energy (stimuli) that could be employed by water-related and underwater sensing systems were used as the basis for organizing the sensor descriptor fields. In addition, the sensing method (direct or indirect), the sensor involvement (active or passive) and the sensor availability (commercial product, laboratory prototype, development project, or theoretical study) were included in the set of major sensor descriptors.

The environmental descriptor fields were determined by considering the relevance of the environment at the sensor, the environment at the object, the preferred sensor platform, and the sensor-object proximity. These environmental factors were important in considering which of several possible stimuli would be appropriate for the required environmental morphology. For example, if the sensor were in air and the object underwater, sound would not be an appropriate stimulus because of the attenuation suffered at the water-air interface.

Three major object descriptors were included in the sensor taxonomy because of their importance to sensor operation. These were the nature of the object sensed (discrete, distributed or continuous); the object-stimulus interaction (was the object itself active or did it simply modify the sensing stimulus in some way); and the type of information about the object that was desired. (Was information transferred between object and sensor? Was only one-dimensional synoptic-type information obtained or was multi-dimensional, image-type information obtained?)

The sensor taxonomy which evolved is shown in Table 3.2. It is recognized that this format may have more descriptor fields than are required for many sensor morphologies. The chief benefits of retaining as much generality as is practical may be seen by considering how the taxonomy is to be used. Initially, this format is to be used in developing a data base containing information on present sensing technology. The same taxonomy format will then be used to organize specific morphologies for searching the data base to determine how well existing sensor technology matches a required Coast Guard application. Thus the sensor descriptor information in the data file must be as

## TABLE 3.2. SENSOR TAXONOMY

SENSOR TITLE OR REF. NO. ________________

**5. SENSOR DESCRIPTORS**

**5.1 Function (circle all appropriate)**

1 Navigation    4 Parametric Measurement
2 Detection    5 Information Transfer
3 Surveillance (monitoring)

**5.1.1 Specific use**

________________
(short description)

**5.2 Sensing Method (Circle 1)**

1 Direct
2 Indirect

(If indirect, show which of descriptors apply to the direct (D) and to the indirect (I) stimuli)

**5.3 Sensor Involvement (Circle 1)**

1 Active    2 Passive

**5.4 Stimulus Used (circle all appropriate)**

| 1 Mechanical | 2 Acoustic | 3 Force Field |
|---|---|---|
| 1 Fluid Motion | 1 Vibration | 1 Gravitation |
| 2 Lin. or Rd. Motion | 2 L.F. Sound | 2 Magnetic |
| 3 Nuclear Particles | 3 M.F. Sound | 3 Electrostatic |
| 4 Heat | 4 H.F. Sound | 4 Electromotive |
| 5 Pressure | | |

| 4 Electromagnetic | 5 Chemical |
|---|---|
| 1 Ionizing waves | 1 Molecular bond |
| 2 Light | 2 Electrochemical |
| 3 Microwaves | 3 Thermochemical |
| 4 Radio waves | |

**5.5 Stimulus Property Sensed (circle all appropriate)**

| Scalar | Vector | Time-Frequency |
|---|---|---|
| 1 off-on | 1 direction | 1 time-interval |
| 2 amplitude | 2 force | 2 period |
| 3 temperature | 3 displacement | 3 frequency |
| 4 volume | 4 velocity | 4 spectrum |
| 5 voltage/ current | 5 acceleration | 5 color |
| 6 chemical change | 6 polarization | |

**5.6 Sensor Availability (Circle 1)**

1 Commercial Product
2 Laboratory Prototype
3 Development Project (available within 3 years)
4 Theoretical Study (availability not known)

**6. ENVIRONMENT DESCRIPTORS**

**6.1 At Sensor (circle all appropriate)**

1 Space    4 Underwater
2 Air    5 Bottom
3 Surface    6 Sub-bottom

**6.2 At Object (circle all appropriate)**

1 Space    4 Underwater
2 Air    5 Bottom
3 Surface    6 Sub-bottom

**6.3 Sensor Platform (circle all appropriate)**

1 Fixed    4 Free fall
2 Mobile, controlled    5 Hand held
3 Mobile, free    6 Tethered

**6.4 Sensor Object Proximity**

1 Contact
2 Near
3 Remote

**7. OBJECT DESCRIPTORS**

**7.1 Nature of Object(s) Sensed (circle all appropriate)**

| 1 Discrete Object (or medium boundary) | 2 Distributed Objects (within medium) | Continuous Medium |
|---|---|---|
| 1 Animate (mobile) | 1 Animate (mobile) | 1 Solid |
| 2 Solid | 2 Particles | 2 Liquid |
| 3 Gelatinous | 3 Droplets | 3 Gas |
| 4 Liquid | 4 Bubbles | |
| 5 Film | | |
| 6 Gas | | |

**7.2 Object-Stimulus Interaction (circle all appropriate)**

| 1 Active Object | 2 Passive Object |
|---|---|
| 1 Cooperative Emission | 1 Reflection |
| 2 Stimulated Emission | 2 Refraction |
| 3 Spontaneous Emission | 3 Scattering |
| | 4 Absorption |
| | 5 Field Perturbation |
| | 6 Indirect |

**7.3 Object Information (circle all appropriate)**

| 1 Information Transfer | 2 Synoptic Information | 3 Geometric Information |
|---|---|---|
| 1 Communication | 1 Detect Presence | 1 Volumetric |
| 2 Data Telemetry | 2 Identify Features | 2 2-D Image of Surface |
| 3 System Control | 3 Measure Properties | 3 3-D Image of Surface |
| | 4 Determine Motion or Change of Form | 4 3-D Image plus Interior Details |

complete as practical, since it will not be possible to develop search morphologies which need descriptor fields not included in the data base.

The generality of the sensor taxonomy will allow both user-oriented and developer-oriented searches to be made. For example, if a specific sensor use is identified and a search of the data base is to be made to determine the number of sensors that may be applicable, it is only necessary to specify a morphology based on the known environmental and object descriptors. The stimulus descriptors do not need to be specified since, presumably any sensor that meets the environment and object information requirements should be examined as a potentially applicable candidate.

A sensor developer probably will have specific types of stimulus technology available and will wish to know how these stimuli are used in existing sensor systems and what environmental factors must be considered in the design of new sensor systems. Thus a morphology which includes a major set of sensor descriptors and some object descriptors would be appropriate for a data base search to see how many existing sensors were available for various environmental combinations. The combinations which were not provided for by present technology would be identified by the search, and a decision could be made as to whether or not a real technical need existed.

# 4. PRESENT SENSOR TECHNOLOGY – OBTAINING THE DATA BASE

## 4.1 Sensor Information Search Procedure

Because of the broad scope of this study, it was necessary to obtain a data base of sensor information which was representative of the state of the art in all of the relevant technologies. The acquisition of a comprehensive set of information in any specific sensor area, such as underwater acoustic detection systems, would consume an excessive amount of contract resources. Thus the data base composition had to be a compromise between breadth and depth.

State-of-the-art sensor information was obtained after organizing a key word list covering all of the sensor fields relevant to Coast Guard activities. This key word list was supplied to the Defense Documentation Center (DDC) for a literature search of Department of Defense Reports including classified information through the level of SECRET. In addition, the list was also used for a search by the National Technical Information Service (NTIS) of all government sponsored reports from nonDOD agencies. These searches concentrated on the past five year period.

In addition to these searches, a review of abstracts in the Engineering Index was conducted along with a survey of selected recent technical journals and trade magazines.

The bibliographies resulting from the DDC and NTIS searches were reviewed and reprints of selected items requested. When these reprints were received, a second review process was followed to select the items to be entered in the sensor data base.

Information about commercially available sensors and about sensors now under development was obtained by a letter survey of manufacturers, government laboratories, and private research institutions. A total of 259 letters were sent out and 115 replies received. Of the total number of replies received, 82 contained information useful for the study.

## 4.2 Organization of the Sensor Data Base

Each sensor system to be entered in the data base was cataloged using a standard 2-page format. Page 1 contained a general description of the device together with manufacturer or author information as shown in Table 4.1. Page 2 contained the taxonomy information as shown previously in Table 3.2. The taxonomy information was determined by a reviewer familiar with the appropriate sensor technology. Following a review of the sensor information, the correct descriptors on the taxonomy sheet (Table 3.2) were selected. A key number was then assigned to the data entry and the page 2 information was then coded into a computer file. The page 1 information was organized into a printed catalog and comprises two appendices to this report. Appendix C contains the unclassified sensor information and Appendix D the classified information. These two appendices are separately bound.

It was necessary to establish some general rules to insure consistency within the data base in reviewing the sensor information and specifying the appropriate entries on the taxonomy sheet. Thus, even though a certain procedure might subsequently be determined to be inaccurate, at least it will be consistently inaccurate and a general correction can be applied. Table 4.2 contains a list of the general assumptions used in determining the "correct" taxonomy descriptor.

TABLE 4.1. WATER-RELATED SENSOR DATA FORM

1. Instrument or System Descriptive Title, Model No.

   or

   Technical Paper Title

2. Manufacturer and Address

   or

   Authors and Address (usually employer's address)

3. Date of Information

   or

   Technical Reference Citation (Follow ASA Format — example — Journal, Volume, No., pages, date)

4. List of Specifications

   or

   Abstract

TABLE 4.2. TAXONOMY DESCRIPTOR DETERMINATION

| Descriptor No. | Comment |
| --- | --- |
| 5.2 Sensing Method | If the stimulus employed by the sensor does not obtain information directly from the object, the method is "indirect". Example: An electromagnetic water current meter indirectly measures flow speed by directly detecting the voltage induced across a set of electrodes placed in a magnetic field |
| 6.4 Sensor-Object Proximity | The sensor is considered "near" the object if it is within a distance less than the overall dimensions of the sensing element itself. |
| 7.1 Nature of Object Sensed | "Continuous Medium" is appropriate if the sensor works with properties of the medium itself rather than those at a boundary or object within a medium. |
| 7.2 Object-Stimulus Interaction | "Stimulated Emission" results from conversion of sensor stimulus energy to another frequency which is reradiated; or if stored energy is released by the object, the released amount is related to the energy or bandwidth of the sensor stimulus.<br><br>"Cooperative Emission" may be initiated by the sensor stimulus or may occur at expected intervals. It is not dependent on energy and bandwidth properties of the sensor stimulus. |

# 5. ANALYSIS OF UNDERWATER AND WATER-RELATED TECHNOLOGY AS APPLIED TO COAST GUARD NEEDS

## 5.1 Establishment of Mission Scenarios and Corresponding Sensor Templates

Since the concept of morphological analysis is applied to sensor technology in this study, it is convenient and consistent to also apply it to the selected Coast Guard activities discussed in Sec. 2. This will help insure that all possible mission "scenarios" are recognized and that the sensor systems which would assist, or be required by, these missions are considered. Ideally, each mission scenario implied by a given morphological combination should be examined for its possible sensor requirements. This was not possible because of the large number of mission scenarios developed by this procedure.

To reduce the procedure to manageable dimensions and still retain the generality of the morphological method, the following analysis sequence was devised:

1. Develop a mission taxonomy for selected general CG activities.

2. Develop a general "template" for all sensor descriptors implied by the mission taxonomy using the sensor taxonomy sheet.*

3. Search the data base using the general template.

4. Depending on results, repeat searches using progressively fewer search fields (in order of priority relating to mission) until a number of nonrelevant sensor types appear in output. Several priority schedules may be tested. To insure that the search field is sufficiently broad, some nonrelevant output must be permitted.

---

*The "template" in this application is the list of sensor descriptors that the computer is requested to search for. All sensors in the data base which have matching descriptors are identified by key number, title, and specific use on the output sheets.

5. Select a "best" set of search fields and printout a general morphological combination set using the template items in the selected search fields. The final set of morphological fields should consider not only those defined in Step 4 by the present data base, but also should include the fields relevant to future sensor technology from the general template of Step 2.

6. Analyze the morphological list for combinations which are relevant but for which existing sensor technology is inadequate.

7. Outline appropriate procedures for filling the indicated technological gaps.

The general mission taxonomies developed for Step 1 in this procedure were restricted primarily to cover operational descriptors which might have water-related sensor implications, hence some items of general operational procedure may be omitted. What is hoped is that no significant water-related mission descriptor has been overlooked.

The general mission taxonomies and corresponding general sensor templates are shown on the following pages. In some cases the general mission taxonomy encompassed such a wide range of possible sensor descriptors that it was necessary to select some specific mission areas within the general taxonomy to obtain a better focus for the analysis procedure.

#### 5.1.1 Taxonomy of search and rescue

1. *Search Area*

Harbor, seacoast, Continental Shelf, Deep Ocean

2. *Distressed Object*

Personnel, small craft (open), coastal vessels (decked pleasure craft, fishing vessels, small commercial vessels), ships (ocean-going), aircraft, submersibles, offshore platforms, isolated bases.

3. *Search Vehicle*

None, satellite, aircraft, airship, small boats (CG or private, single or several), conventional USCG cutter (ocean-going), high-speed surface craft (hydrofoils, surface-effect-craft), semisubmersible surface craft, submersible.

4. *Rescue Vehicle*

None, aircraft, airship, small boats, cutter, high-speed surface craft, semisubmersible surface vessel, submersible.

SENSOR TITLE OR REF. NO. "Search" Sensor Template

## 5. SENSOR DESCRIPTORS

**5.1 Function (circle all appropriate)**

1 Navigation
2 Detection
3 Surveillance (monitoring)
4 Parametric Measurement
5 Information Transfer

**5.1.1 Specific use**

(short description)

**5.2 Sensing Method (Circle 1)**

1 Direct
2 Indirect

(If indirect, show which of descriptors apply to the direct (D) and to the indirect (I) stimuli)

**5.3 Sensor Involvement (Circle 1)**

1 Active
2 Passive

**5.4 Stimulus Used (circle all appropriate)**

1 Mechanical
1 Fluid Motion
2 Lin. or Rd. Motion
3 Nuclear Particles
4 Heat
5 Pressure

2 Acoustic
1 Vibration
2 L.F. Sound
3 M.F. Sound
4 H.F. Sound

3 Force Field
1 Gravitation
2 Magnetic
3 Electrostatic
4 Electromotive

4 Electromagnetic
1 Ionizing waves
2 Light
3 Microwaves
4 Radio waves

5 Chemical
1 Molecular bond
2 Electrochemical
3 Thermochemical

| Analysis Sequence | | Found |
|---|---|---|
| Full Template Search | | 53 Sensors |
| Field 5.4 Not Specified | | 62 |
| 5.4, 5.1 " " | | 66 |
| 5.4, 5.1, 6.3 " | | 66 |
| 5.4, 5.1, 6.3, 7.2 | Not Specified | 66 |
| 5.4, 5.1, 6.3, 7.2, 7.3 | | 105 |

## 6. ENVIRONMENT DESCRIPTORS

**6.1 At Sensor (circle all appropriate)**

1 Space
2 Air
3 Surface
4 Underwater
5 Bottom
6 Sub-bottom

**6.2 At Object (circle all appropriate)**

1 Space
2 Air
3 Surface
4 Underwater
5 Bottom
6 Sub-bottom

**6.3 Sensor Platform (circle all appropriate)**

1 Fixed
2 Mobile, controlled
3 Mobile, free
4 Free fall
5 Hand held
6 Tethered

**6.4 Sensor Object Proximity**

1 Contact
2 Near
3 Remote

## 7. OBJECT DESCRIPTORS

**7.1 Nature of Object(s) Sensed (circle all appropriate)**

1 Discrete Object (or medium boundary)
1 Animate (mobile)
2 Solid
3 Gelatinous
4 Liquid
5 Film
6 Gas

2 Distributed Objects (within medium)
1 Animate (mobile)
2 Particles
3 Droplets
4 Bubbles

Continuous Medium
1 Solid
2 Liquid
3 Gas

**7.2 Object-Stimulus Interaction (circle all appropriate)**

1 Active Object
1 Cooperative Emission
2 Stimulated Emission
3 Spontaneous Emission

2 Passive Object
1 Reflection
2 Refraction
3 Scattering
4 Absorption
5 Field Perturbation
6 Indirect

**7.3 Object Information (circle all appropriate)**

1 Information Transfer
1 Communication
2 Data Telemetry
3 System Control

2 Synoptic Information
1 Detect Presence
2 Identify Features
3 Measure Properties
4 Determine Motion or Change of Form

3 Geometric Information
1 Volumetric
2 2-D Image of Surface
3 3-D Image of Surface
4 3-D Image plus Interior Details

### 5.1.1 Taxonomy of search and rescue

1. *Search Area*

Harbor, Seacost, Continental Shelf, Deep Ocean

2. *Distressed Object*

Personnel, small craft (open), coastal vessels (decked) pleasure craft, fishing vessels, small commerical vessels), ships (ocean-going), aircraft, submersibles, offshore platforms, isoloated bases.

3. *Search Vehicle*

None, satellite, aircraft, airship, small boats (CG or private, single, or several), conventional USCG cutter (ocean-going), high-speed surface craft (hydrofoils, surface-effect-craft), semisubmersible surface craft, submersible.

4. *Rescue Vehicle*

None, aircraft, airship, small boats, cutter, high-speed surface craft, semisubmersible surface vessel, submersible.

THIS PAGE IS REPEATED FOR THE CONVENIENCE OF THE READER.

SENSOR TITLE OR REF. NO. Rescue Sensor Template

5. SENSOR DESCRIPTORS

5.1 Function (circle all appropriate)

1 Navigation
2 Detection
3 Surveillance (monitoring)
4 Parametric Measurement
5 Information Transfer

5.1.1 Specific use

(short description)

5.2 Sensing Method (Circle 1)

1 Direct
2 Indirect

(If indirect, show which of descriptors apply to the direct (D) and to the indirect (I) stimuli)

5.3 Sensor Involvement (Circle 1)

1 Active    2 Passive

5.4 Stimulus Used (circle all appropriate)

| 1 Mechanical | 2 Acoustic | 3 Force Field |
|---|---|---|
| 1 Fluid Motion | 1 Vibration | 1 Gravitation |
| 2 Lin. or Rd. Motion | 2 L.F. Sound | 2 Magnetic |
| 3 Nuclear Particles | 3 M.F. Sound | 3 Electrostatic |
| 4 Heat | 4 H.F. Sound | 4 Electromotive |
| 5 Pressure | | |

| 4 Electromagnetic | 5 Chemical |
|---|---|
| 1 Ionizing waves | 1 Molecular bond |
| 2 Light | 2 Electrochemical |
| 3 Microwaves | 3 Thermochemical |
| 4 Radio waves | |

| Analysis Sequence | Found |
|---|---|
| Full Template Search | 35 Sensors |
| Field 5.4 Not Specified | 36 |
| 5.4, 5.1 Not Specified | 41 |
| 5.4, 5.1, 7.2 Not Specified | 41 |

6. ENVIRONMENT DESCRIPTORS

6.1 At Sensor (circle all appropriate)

1 Space
2 Air
3 Surface
4 Underwater
5 Bottom
6 Sub-bottom

6.2 At Object (circle all appropriate)

1 Space
2 Air
3 Surface
4 Underwater
5 Bottom
6 Sub-bottom

6.3 Sensor Platform (circle all appropriate)

1 Fixed
2 Mobile, controlled
3 Mobile, free
4 Free fall
5 Hand held
6 Tethered

6.4 Sensor Object Proximity

1 Contact
2 Near
3 Remote

7. OBJECT DESCRIPTORS

7.1 Nature of Object(s) Sensed (circle all appropriate)

| 1 Discrete Object (or medium boundary) | 2 Distributed Objects (within medium) | Continuous Medium |
|---|---|---|
| 1 Animate (mobile) | 1 Animate (mobile) | 1 Solid |
| 2 Solid | 2 Particles | 2 Liquid |
| 3 Gelatinous | 3 Droplets | 3 Gas |
| 4 Liquid | 4 Bubbles | |
| 5 Film | | |
| 6 Gas | | |

7.2 Object-Stimulus Interaction (circle all appropriate)

| 1 Active Object | 2 Passive Object |
|---|---|
| 1 Cooperative Emission | 1 Reflection |
| 2 Stimulated Emission | 2 Refraction |
| 3 Spontaneous Emission | 3 Scattering |
| | 4 Absorption |
| | 5 Field Perturbation |
| | 6 Indirect |

7.3 Object Information (circle all appropriate)

| 1 Information Transfer | 2 Synoptic Information | 3 Geometric Information |
|---|---|---|
| 1 Communication | 1 Detect Presence | 1 Volumetric |
| 2 Data Telemetry | 2 Identify Features | 2 2-D Image of Surface |
| 3 System Control | 3 Measure Properties | 3 3-D Image of Surface |
| | 4 Determine Motion or Change of Form | 4 3-D Image plus Interior Details |

### 5.1.2 Taxonomy of oil spill detection, classification, and removal

1. *Location*

River, harbor, near shore (beach), continental shelf (fishing grounds), mid ocean.

2. *Detection*

Satellite, aircraft, motor vessel, cutter, outside agency (or private vessel).

3. *Classification*

Remote sensor, in-situ sampling and analysis, sampling and remote analysis, none.

4. *Removal*

By party at fault, CG small craft, specialized sweep vessel, CG strike team and spill barges, CG battalion and specialized ships.

SENSOR TITLE OR REF. NO. Oil Spill Detection Template

**5. SENSOR DESCRIPTORS**

**5.1 Function (circle all appropriate)**

| | |
|---|---|
| 1 Navigation | 4 Parametric Measurement |
| 2 Detection | 5 Information Transfer |
| 3 Surveillance (monitoring) | |

**5.1.1 Specific use**

(short description)

**5.2 Sensing Method (Circle 1)**

1 Direct
2 Indirect

(If indirect, show which of descriptors apply to the direct (D) and to the indirect (I) stimuli)

**5.3 Sensor Involvement (Circle 1)**

1 Active    2 Passive

**5.4 Stimulus Used (circle all appropriate)**

| 1 Mechanical | 2 Acoustic | 3 Force Field |
|---|---|---|
| 1 Fluid Motion | 1 Vibration | 1 Gravitation |
| 2 Lin. or Rd. Motion | 2 L.F. Sound | 2 Magnetic |
| 3 Nuclear Particles | 3 M.F. Sound | 3 Electrostatic |
| 4 Heat | 4 H.F. Sound | 4 Electromotive |
| 5 Pressure | | |

| 4 Electromagnetic | 5 Chemical |
|---|---|
| 1 Ionizing waves | 1 Molecular bond |
| 2 Light | 2 Electrochemical |
| 3 Microwaves | 3 Thermochemical |
| 4 Radio waves | |

| Analysis Sequence | Found |
|---|---|
| Full Template Search | 29 Sensors |
| Field 5.1 Not Specified | 38 |
| 5.1, 7.3 Not Specified | 50 |

**6. ENVIRONMENT DESCRIPTORS**

**6.1 At Sensor (circle all appropriate)**

| | |
|---|---|
| 1 Space | 4 Underwater |
| 2 Air | 5 Bottom |
| 3 Surface | 6 Sub-bottom |

**6.2 At Object (circle all appropriate)**

| | |
|---|---|
| 1 Space | 4 Underwater |
| 2 Air | 5 Bottom |
| 3 Surface | 6 Sub-bottom |

**6.3 Sensor Platform (circle all appropriate)**

| | |
|---|---|
| 1 Fixed | 4 Free fall |
| 2 Mobile, controlled | 5 Hand held |
| 3 Mobile, free | 6 Tethered |

**6.4 Sensor Object Proximity**

1 Contact
2 Near
3 Remote

**7. OBJECT DESCRIPTORS**

**7.1 Nature of Object(s) Sensed (circle all appropriate)**

| 1 Discrete Object (or medium boundary) | 2 Distributed Objects (within medium) | Continuous Medium |
|---|---|---|
| 1 Animate (mobile) | 1 Animate (mobile) | 1 Solid |
| 2 Solid | 2 Particles | 2 Liquid |
| 3 Gelatinous | 3 Droplets | 3 Gas |
| 4 Liquid | 4 Bubbles | |
| 5 Film | | |
| 6 Gas | | |

**7.2 Object-Stimulus Interaction (circle all appropriate)**

| 1 Active Object | 2 Passive Object |
|---|---|
| 1 Cooperative Emission | 1 Reflection |
| 2 Stimulated Emission | 2 Refraction |
| 3 Spontaneous Emission | 3 Scattering |
| | 4 Absorption |
| | 5 Field Perturbation |
| | 6 Indirect |

**7.3 Object Information (circle all appropriate)**

| 1 Information Transfer | 2 Synoptic Information | 3 Geometric Information |
|---|---|---|
| 1 Communication | 1 Detect Presence | 1 Volumetric |
| 2 Data Telemetry | 2 Identify Features | 2 2-D Image of Surface |
| 3 System Control | 3 Measure Properties | 3 3-D Image of Surface |
| | 4 Determine Motion or Change of Form | 4 3-D Image plus Interior Details |

### 5.1.2 Taxonomy of oil spill detection, classification, and removal

1. *Location*

River, harbor, near shore (beach), continental shelf (fishing grounds), mid ocean.

2. *Detection*

Satellite, aircraft, motor vessel, cutter, outside agency (or private vessel).

3. *Classification*

Remote sensor, in-situ sampling and analysis, sampling and remote analysis, none.

4. *Removal*

By party at fault, CG small craft, specialized sweep vessel, CG strike team and spill barges, CG battalion and specialized ships.

THIS PAGE IS REPEATED FOR THE CONVENIENCE OF THE READER.

SENSOR TITLE OR REF. NO. Oil Spill Classification Template

5. SENSOR DESCRIPTORS

5.1 Function (circle all appropriate)

1 Navigation
2 Detection
3 Surveillance (monitoring)
4 Parametric Measurement
5 Information Transfer

5.1.1 Specific use

(short description)

5.2 Sensing Method (Circle 1)

1 Direct
2 Indirect

(If indirect, show which of descriptors apply to the direct (D) and to the indirect (I) stimuli)

5.3 Sensor Involvement (Circle 1)

1 Active 2 Passive

5.4 Stimulus Used (circle all appropriate)

| 1 Mechanical | 2 Acoustic | 3 Force Field |
|---|---|---|
| 1 Fluid Motion | 1 Vibration | 1 Gravitation |
| 2 Lin. or Rd. Motion | 2 L.F. Sound | 2 Magnetic |
| 3 Nuclear Particles | 3 M.F. Sound | 3 Electrostatic |
| 4 Heat | 4 H.F. Sound | 4 Electromotive |
| 5 Pressure | | |

| 4 Electromagnetic | 5 Chemical |
|---|---|
| 1 Ionizing waves | 1 Molecular bond |
| 2 Light | 2 Electrochemical |
| 3 Microwaves | 3 Thermochemical |
| 4 Radio waves | |

| Analysis Sequence | Found |
|---|---|
| Full Template Search | 68 Sensors |
| Field 5.1 Not Specified | 69 |
| 5.1, 7.2 Not Specified | 72 |
| 5.1, 7.2, *7.1 Not Specified | 50 |

6. ENVIRONMENT DESCRIPTORS

6.1 At Sensor (circle all appropriate)

1 Space
2 Air
3 Surface
4 Underwater
5 Bottom
6 Sub-bottom

6.2 At Object (circle all appropriate)

1 Space
2 Air
3 Surface
4 Underwater
5 Bottom
6 Sub-bottom

6.3 Sensor Platform (circle all appropriate)

1 Fixed
2 Mobile, controlled
3 Mobile, free
4 Free fall
5 Hand held
6 Tethered

6.4 Sensor Object Proximity

1 Contact
2 Near
3 Remote

7. OBJECT DESCRIPTORS

7.1 Nature of Object(s) Sensed (circle all appropriate)

| 1 Discrete Object (or medium boundary) | 2 Distributed Objects (within medium) | Continuous Medium |
|---|---|---|
| 1 Animate (mobile) | 1 Animate (mobile) | 1 Solid |
| 2 Solid | 2 Particles * | 2 Liquid |
| 3 Gelatinous | 3 Droplets * | 3 Gas * |
| 4 Liquid | 4 Bubbles | |
| 5 Film | | |
| 6 Gas | | |

7.2 Object-Stimulus Interaction (circle all appropriate)

| 1 Active Object | 2 Passive Object |
|---|---|
| 1 Cooperative Emission | 1 Reflection |
| 2 Stimulated Emission | 2 Refraction |
| 3 Spontaneous Emission | 3 Scattering |
| | 4 Absorption |
| | 5 Field Perturbation |
| | 6 Indirect |

7.3 Object Information (circle all appropriate)

| 1 Information Transfer | 2 Synoptic Information | 3 Geometric Information |
|---|---|---|
| 1 Communication | 1 Detect Presence | 1 Volumetric |
| 2 Data Telemetry | 2 Identify Features | 2 2-D Image of Surface |
| 3 System Control | 3 Measure Properties | 3 3-D Image of Surface |
| | 4 Determine Motion or Change of Form | 4 3-D Image plus Interior Details |

### 5.1.3 Taxonomy of offshore law enforcement

1. *Suspect "vessel"*

Large ship, fishing vessel, small craft, submersible, swimmer.

2. *Detection (platform)*

Shore base, satellite, aircraft, airship, cutter, high speed surface craft, semisubmersible, submersible.

3. *Interception (platform)*

Interception made by detecting vessel, aircraft, airship, cutter, high-speed surface craft, semisubmersible, submersible.

4. *Identification (stimulus)*

Light (visual), electromagnetic (radio), acoustic (direct voice or electronically augmented sound), imaging methods (radar, IR viewers, photographic, satellite).

5. *Enforcement (procedure)*

No action needed, transmitted message (visual, radio, or acoustic), close inspection (overflight or pass-by), board and search, seizure of vessel.

6. *Follow-up (procedure)*

None required, continued surveillance, escorted passage, transfer of command and control.

## Offshore Law Enforcement

SENSOR TITLE OR REF. NO. Template

### 5. SENSOR DESCRIPTORS

**5.1 Function (circle all appropriate)**

| | |
|---|---|
| 1 Navigation | 4 Parametric Measurement |
| 2 Detection | 5 Information Transfer |
| 3 Surveillance (monitoring) | |

**5.1.1 Specific use**

(short description)

**5.2 Sensing Method (Circle 1)**

1 Direct
2 Indirect

(If indirect, show which of descriptors apply to the direct (D) and to the indirect (I) stimuli)

**5.3 Sensor Involvement (Circle 1)**

1 Active    2 Passive

**5.4 Stimulus Used (circle all appropriate)**

| 1 Mechanical | 2 Acoustic | 3 Force Field |
|---|---|---|
| 1 Fluid Motion | 1 Vibration | 1 Gravitation |
| 2 Lin. or Rd. Motion | 2 L.F. Sound | 2 Magnetic |
| 3 Nuclear Particles | 3 M.F. Sound | 3 Electrostatic |
| 4 Heat | 4 H.F. Sound | 4 Electromotive |
| 5 Pressure | | |

| 4 Electromagnetic | 5 Chemical |
|---|---|
| 1 Ionizing waves | 1 Molecular bond |
| 2 Light | 2 Electrochemical |
| 3 Microwaves | 3 Thermochemical |
| 4 Radio waves | |

| Analysis Sequence | Found |
|---|---|
| Full Template Search | 61 Sensors |
| Field 5.4 Not Specified | 65 |
| 5.4, 5.1 Not Specified | 70 |
| 5.4, 5.1, 7.2 Not Specified | 82 |

### 6. ENVIRONMENT DESCRIPTORS

**6.1 At Sensor (circle all appropriate)**

| | |
|---|---|
| 1 Space | 4 Underwater |
| 2 Air | 5 Bottom |
| 3 Surface | 6 Sub-bottom |

**6.2 At Object (circle all appropriate)**

| | |
|---|---|
| 1 Space | 4 Underwater |
| 2 Air | 5 Bottom |
| 3 Surface | 6 Sub-bottom |

**6.3 Sensor Platform (circle all appropriate)**

| | |
|---|---|
| 1 Fixed | 4 Free fall |
| 2 Mobile, controlled | 5 Hand held |
| 3 Mobile, free | 6 Tethered |

**6.4 Sensor Object Proximity**

1 Contact
2 Near
3 Remote

### 7. OBJECT DESCRIPTORS

**7.1 Nature of Object(s) Sensed (circle all appropriate)**

| 1 Discrete Object (or medium boundary) | 2 Distributed Objects (within medium) | Continuous Medium |
|---|---|---|
| 1 Animate (mobile) | 1 Animate (mobile) | 1 Solid |
| 2 Solid | 2 Particles | 2 Liquid |
| 3 Gelatinous | 3 Droplets | 3 Gas |
| 4 Liquid | 4 Bubbles | |
| 5 Film | | |
| 6 Gas | | |

**7.2 Object-Stimulus Interaction (circle all appropriate)**

| 1 Active Object | 2 Passive Object |
|---|---|
| 1 Cooperative Emission | 1 Reflection |
| 2 Stimulated Emission | 2 Refraction |
| 3 Spontaneous Emission | 3 Scattering |
| | 4 Absorption |
| | 5 Field Perturbation |
| | 6 Indirect |

**7.3 Object Information (circle all appropriate)**

| 1 Information Transfer | 2 Synoptic Information | 3 Geometric Information |
|---|---|---|
| 1 Communication | 1 Detect Presence | 1 Volumetric |
| 2 Data Telemetry | 2 Identify Features | 2 2-D Image of Surface |
| 3 System Control | 3 Measure Properties | 3 3-D Image of Surface |
| | 4 Determine Motion or Change of Form | 4 3-D Image plus Interior Details |

### 5.1.4 Ice operations taxonomy

1. *Location*

Arctic, Antarctic, Great Lakes, Northern Ports, Northern Rivers.

2. *Ice Type*

River (fresh water), slush, pancake, field, pack, glacial (iceberg).

3. *Mission Purpose*

Ice measurement and mapping, search and rescue, prevention of flooding, facilitate marine transportation (ice breaking), law enforcement, pollution cleanup support, ice station, support of other agencies.

4. *Anti-Ice Procedure*

Avoidance, mechanical (ice breaking), thermal (increasing heat input to ice), hydraulic (increasing water motion to prevent freezing).

SENSOR TITLE OR REF. NO. Ice Measurement and Mapping Template

**5. SENSOR DESCRIPTORS**

**5.1 Function (circle all appropriate)**

| | |
|---|---|
| 1 Navigation | 4 Parametric Measurement |
| 2 Detection | 5 Information Transfer |
| 3 Surveillance (monitoring) | |

| Analysis Sequence | Found |
|---|---|
| Full Template Search | 19 Sensors |
| Field 5.5 Not Specified | 25 |
| 5.4 Not Specified, * added to 5.5, 7.2 | 20 |
| 5.1, 5.5 Not Spec., ** added to 5.4 | 31 |
| 5.1, 5.4, 5.5 Not Specified | 33 |
| 5.1, 5.4, 5.5, 7.2 Not Specified | 46 |

**5.4 Stimulus Used (circle all appropriate)**

| 1 Mechanical | 2 Acoustic | 3 Force Field |
|---|---|---|
| 1 Fluid Motion | 1 Vibration | 1 Gravitation |
| 2 Lin. or Rd. Motion | 2 L.F. Sound | 2 Magnetic ** |
| 3 Nuclear Particles | 3 M.F. Sound | 3 Electrostatic |
| 4 Heat | 4 H.F. Sound | 4 Electromotive |
| 5 Pressure | | |

| 4 Electromagnetic | 5 Chemical |
|---|---|
| 1 Ionizing waves | 1 Molecular bond |
| 2 Light | 2 Electrochemical |
| 3 Microwaves | 3 Thermochemical |
| 4 Radio waves | |

**5.5 Stimulus Property Sensed (circle all appropriate)**

| Scalar | Vector | Time-Frequency |
|---|---|---|
| 1 off-on | 1 direction * | 1 time-interval |
| 2 amplitude | 2 force | 2 period |
| 3 temperature | 3 displacement | 3 frequency |
| 4 volume | 4 velocity | 4 spectrum |
| 5 voltage/ current | 5 acceleration | 5 color |
| 6 chemical change | 6 polarization | |

**5.6 Sensor Availability (Circle 1)**

1 Commercial Product
2 Laboratory Prototype
3 Development Project (available within 3 years)
4 Theoretical Study (availability not known)

**6. ENVIRONMENT DESCRIPTORS**

**6.1 At Sensor (circle all appropriate)**

| | |
|---|---|
| 1 Space | 4 Underwater |
| 2 Air | 5 Bottom |
| 3 Surface | 6 Sub-bottom |

**6.2 At Object (circle all appropriate)**

| | |
|---|---|
| 1 Space | 4 Underwater |
| 2 Air | 5 Bottom |
| 3 Surface | 6 Sub-bottom |

**6.3 Sensor Platform (circle all appropriate)**

| | |
|---|---|
| 1 Fixed | 4 Free fall |
| 2 Mobile, controlled | 5 Hand held |
| 3 Mobile, free | 6 Tethered |

**6.4 Sensor Object Proximity**

1 Contact
2 Near
3 Remote

**7. OBJECT DESCRIPTORS**

**7.1 Nature of Object(s) Sensed (circle all appropriate)**

| 1 Discrete Object (or medium boundary) | 2 Distributed Objects (within medium) | Continuous Medium |
|---|---|---|
| 1 Animate (mobile) | 1 Animate (mobile) | 1 Solid |
| 2 Solid | 2 Particles | 2 Liquid |
| 3 Gelatinous | 3 Droplets | 3 Gas |
| 4 Liquid | 4 Bubbles | |
| 5 Film | | |
| 6 Gas | | |

**7.2 Object-Stimulus Interaction (circle all appropriate)**

| 1 Active Object | 2 Passive Object |
|---|---|
| 1 Cooperative Emission | 1 Reflection |
| 2 Stimulated Emission | 2 Refraction |
| 3 Spontaneous Emission | 3 Scattering |
| | 4 Absorption |
| | 5 Field Perturbation * |
| | 6 Indirect |

**7.3 Object Information (circle all appropriate)**

| 1 Information Transfer | 2 Synoptic Information | 3 Geometric Information |
|---|---|---|
| 1 Communication | 1 Detect Presence | 1 Volumetric |
| 2 Data Telemetry | 2 Identify Features | 2 2-D Image of Surface |
| 3 System Control | 3 Measure Properties | 3 3-D Image of Surface |
| | 4 Determine Motion or Change of Form | 4 3-D Image plus Interior Details |

### 5.1.4 Ice operations taxonomy

1. *Location*

Arctic, Antarctic, Great Lakes, Northern Ports, Northern Rivers.

2. *Ice Type*

River (fresh water), slush, pancake, field, pack, glacial (iceberg).

3. *Mission Purpose*

Ice measurement and mapping, search and rescue, prevention of flooding, facilitate marine transportation (ice breaking), law enforcement, pollution cleanup support, ice station, support of other agencies.

4. *Anti-Ice Procedure*

Avoidance, mechanical (ice breaking), thermal (increasing heat input to ice), hydraulic (increasing water motion to prevent freezing).

SENSOR TITLE OR REF. NO. Icebreaking Template

## 5. SENSOR DESCRIPTORS

**5.1 Function (circle all appropriate)**

1 Navigation
2 Detection
3 Surveillance (monitoring)
4 Parametric Measurement
5 Information Transfer

**5.1.1 Specific use**

(short description)

**5.2 Sensing Method (Circle 1)**

1 Direct
2 Indirect

(If indirect, show which of descriptors apply to the direct (D) and to the indirect (I) stimuli)

**5.3 Sensor Involvement (Circle 1)**

1 Active 2 Passive

**5.4 Stimulus Used (circle all appropriate)**

| 1 Mechanical | 2 Acoustic | 3 Force Field |
|---|---|---|
| 1 Fluid Motion | 1 Vibration | 1 Gravitation |
| 2 Lin. or Rd. Motion | 2 L.F. Sound | 2 Magnetic * |
| 3 Nuclear Particles | 3 M.F. Sound | 3 Electrostatic |
| 4 Heat | 4 H.F. Sound | 4 Electromotive |
| 5 Pressure | | |

| 4 Electromagnetic | 5 Chemical |
|---|---|
| 1 Ionizing waves | 1 Molecular bond |
| 2 Light | 2 Electrochemical |
| 3 Microwaves | 3 Thermochemical |
| 4 Radio waves | |

| Analysis Sequence | Found |
|---|---|
| Full Template Search | 34 Sensors |
| Field 5.1 Not Specified | 35 |
| 5.1, 7.2 Not Specified | 41 |
| 5.1, 7.2, 6.4 Not Specified | 44 |
| 5.1, 7.2, 6.4 Not Specified plus * in 5.4 added, ** in 7.3 omitted | 47 |

## 6. ENVIRONMENT DESCRIPTORS

**6.1 At Sensor (circle all appropriate)**

1 Space
2 Air
3 Surface
4 Underwater
5 Bottom
6 Sub-bottom

**6.2 At Object (circle all appropriate)**

1 Space
2 Air
3 Surface
4 Underwater
5 Bottom
6 Sub-bottom

**6.3 Sensor Platform (circle all appropriate)**

1 Fixed
2 Mobile, controlled
3 Mobile, free
4 Free fall
5 Hand held
6 Tethered

**6.4 Sensor Object Proximity**

1 Contact
2 Near
3 Remote

## 7. OBJECT DESCRIPTORS

**7.1 Nature of Object(s) Sensed (circle all appropriate)**

| 1 Discrete Object (or medium boundary) | 2 Distributed Objects (within medium) | Continuous Medium |
|---|---|---|
| 1 Animate (mobile) | 1 Animate (mobile) | 1 Solid |
| 2 Solid | 2 Particles | 2 Liquid |
| 3 Gelatinous | 3 Droplets | 3 Gas |
| 4 Liquid | 4 Bubbles | |
| 5 Film | | |
| 6 Gas | | |

**7.2 Object-Stimulus Interaction (circle all appropriate)**

| 1 Active Object | 2 Passive Object |
|---|---|
| 1 Cooperative Emission | 1 Reflection |
| 2 Stimulated Emission | 2 Refraction |
| 3 Spontaneous Emission | 3 Scattering |
| | 4 Absorption |
| | 5 Field Perturbation |
| | 6 Indirect |

**7.3 Object Information (circle all appropriate)**

| 1 Information Transfer | 2 Synoptic Information | 3 Geometric Information |
|---|---|---|
| 1 Communication | 1 Detect Presence | 1 Volumetric |
| 2 Data Telemetry | 2 Identify Features ** | 2 2-D Image of Surface |
| 3 System Control | 3 Measure Properties | 3 3-D Image of Surface ** |
| | 4 Determine Motion or Change of Form | 4 3-D Image plus Interior Details |

### 5.1.5 Port safety and security taxonomy

1. *Type of Port*

Deep-water (offshore), open roadstead, enclosed harbor, estuary, major lake, inland waterway, river.

2. *Navigation Services*

Advisory service for approaching vessels, vessel traffic service in harbor, ship speed surveillance.

3. *Ship Handling Facilities (and Berthed Vessels)*

Oil terminals, LNG terminals, container docks, general cargo piers, fish handling piers, passenger terminals, shipyards, dangerous cargo docks.

4. *Anti-Pollution Measures*

Periodic harbor boat patrols, aerial surveillance, routine surface vessel sampling, fixed continuous monitors (oil, chemical, and nuclear sensors).

5. *Anti-Sabotage and Terrorism Measures*

Local police patrol, routine CG harbor patrol, dock access security check, swimmer and submersible detection system, surveillance of suspect vessels, monitor systems on dangerous cargo docks (explosive vapor and nuclear radiation sensors), special coverage of potential terrorist targets.

SENSOR TITLE OR REF. NO. Port Anti-Sabotage Template

5. SENSOR DESCRIPTORS

5.1 Function (circle all appropriate)

1 Navigation
2 Detection
3 Surveillance (monitoring)
4 Parametric Measurement
5 Information Transfer

5.1.1 Specific use

(short description)

5.2 Sensing Method (Circle 1)

1 Direct
2 Indirect

(If indirect, show which of descriptors apply to the direct (D) and to the indirect (I) stimuli)

5.3 Sensor Involvement (Circle 1)

1 Active    2 Passive

5.4 Stimulus Used (circle all appropriate)

| 1 Mechanical | 2 Acoustic | 3 Force Field |
|---|---|---|
| 1 Fluid Motion | 1 Vibration | 1 Gravitation |
| 2 Lin. or Rd. Motion | 2 L.F. Sound | 2 Magnetic |
| 3 Nuclear Particles | 3 M.F. Sound | 3 Electrostatic |
| 4 Heat | 4 H.F. Sound | 4 Electromotive |
| 5 Pressure | | |

| 4 Electromagnetic | 5 Chemical |
|---|---|
| 1 Ionizing waves | 1 Molecular bond |
| 2 Light | 2 Electrochemical |
| 3 Microwaves | 3 Thermochemical |
| 4 Radio waves | |

| Analysis Sequence | Found |
|---|---|
| Full Template Search | 66 Sensors |
| Field 5.4 Not Specified | 75 |
| 5.4, 6.3 Not Spec., * omitted from 7.2 | 85 |
| 5.4, 6.3, 7.2 Not Specified, * omitted from 7.3 | 98 |
| 5.4, 6.3, 7.2, 6.1 Not Specified | 104 |

6. ENVIRONMENT DESCRIPTORS

6.1 At Sensor (circle all appropriate)

1 Space
2 Air
3 Surface
4 Underwater
5 Bottom
6 Sub-bottom

6.2 At Object (circle all appropriate)

1 Space
2 Air
3 Surface
4 Underwater
5 Bottom
6 Sub-bottom

6.3 Sensor Platform (circle all appropriate)

1 Fixed
2 Mobile, controlled
3 Mobile, free
4 Free fall
5 Hand held
6 Tethered

6.4 Sensor Object Proximity

1 Contact
2 Near
3 Remote

7. OBJECT DESCRIPTORS

7.1 Nature of Object(s) Sensed (circle all appropriate)

| 1 Discrete Object (or medium boundary) | 2 Distributed Objects (within medium) | Continuous Medium |
|---|---|---|
| 1 Animate (mobile) | 1 Animate (mobile) | 1 Solid |
| 2 Solid | 2 Particles | 2 Liquid |
| 3 Gelatinous | 3 Droplets | 3 Gas |
| 4 Liquid | 4 Bubbles | |
| 5 Film | | |
| 6 Gas | | |

7.2 Object-Stimulus Interaction (circle all appropriate)

| 1 Active Object | 2 Passive Object |
|---|---|
| 1 Cooperative Emission | 1 Reflection |
| 2 Stimulated Emission * | 2 Refraction |
| 3 Spontaneous Emission | 3 Scattering |
| | 4 Absorption |
| | 5 Field Perturbation |
| | 6 Indirect |

7.3 Object Information (circle all appropriate)

| 1 Information Transfer | 2 Synoptic Information | 3 Geometric Information |
|---|---|---|
| 1 Communication | 1 Detect Presence | 1 Volumetric |
| 2 Data Telemetry | 2 Identify Features | 2 2-D Image of Surface |
| 3 System Control | 3 Measure Properties | 3 3-D Image of Surface * |
| | 4 Determine Motion or Change of Form | 4 3-D Image plus Interior Details |

### 5.1.6 Aids to navigation taxonomy

1. *Location*

Rivers, harbors, coast, continental shelf, deep ocean.

2. *Environmental Conditions*

Benign, high winds, high seas, ice, rain, fog.

3. *Platform*

Shore mounted, fixed (at sea), tethered (buoy), bottom mounted.

4. *Operating Stimulus*

Visual, acoustic, underwater acoustic, electromagnetic, magnetic, electric.

5. *User Equipment Requirements*

None, chart (light list), general radio receiver, specialized radio receiver, special sensor equipment.

SENSOR TITLE OR REF. NO. Aids to Navigation Template

5. SENSOR DESCRIPTORS

5.1 Function (circle all appropriate)

1 Navigation
2 Detection
3 Surveillance (monitoring)
4 Parametric Measurement
5 Information Transfer *

5.1.1 Specific use

(short description)

5.2 Sensing Method (Circle 1)

1 Direct
2 Indirect

(If indirect, show which of descriptors apply to the direct (D) and to the indirect (I) stimuli)

5.3 Sensor Involvement (Circle 1)

1 Active 2 Passive

5.4 Stimulus Used (circle all appropriate)

| 1 Mechanical | 2 Acoustic | 3 Force Field |
|---|---|---|
| 1 Fluid Motion | 1 Vibration | 1 Gravitation |
| 2 Lin. or Rd. Motion | 2 L.F. Sound | 2 Magnetic |
| 3 Nuclear Particles | 3 M.F. Sound * | 3 Electrostatic |
| 4 Heat | 4 H.F. Sound | 4 Electromotive |
| 5 Pressure | | |

| 4 Electromagnetic | 5 Chemical |
|---|---|
| 1 Ionizing waves | 1 Molecular bond |
| 2 Light * | 2 Electrochemical |
| 3 Microwaves * | 3 Thermochemical |
| 4 Radio waves | |

| Analysis Sequence | Found |
|---|---|
| Full Template Search | 20 Sensors |
| Fields 5.2, 5.4 Not Specified | 27 |
| 5.2, 5.4, 7.3 Not Specified | 28 |
| 5.2, 5.4, 7.3, 5.1 Not Specified | 58 |
| 5.2, 7.3 Not Spec., * omitted from 5.1, 5.4 | 16 |
| 5.1, 5.2, 7.3 Not Spec., * omitted from 5.4 | 37 |

6. ENVIRONMENT DESCRIPTORS

6.1 At Sensor (circle all appropriate)

1 Space
2 Air
3 Surface
4 Underwater
5 Bottom
6 Sub-bottom

6.2 At Object (circle all appropriate)

1 Space
2 Air
3 Surface
4 Underwater
5 Bottom
6 Sub-bottom

6.3 Sensor Platform (circle all appropriate)

1 Fixed
2 Mobile, controlled
3 Mobile, free
4 Free fall
5 Hand held
6 Tethered

6.4 Sensor Object Proximity

1 Contact
2 Near
3 Remote

7. OBJECT DESCRIPTORS

7.1 Nature of Object(s) Sensed (circle all appropriate)

| 1 Discrete Object (or medium boundary) | 2 Distributed Objects (within medium) | Continuous Medium |
|---|---|---|
| 1 Animate (mobile) | 1 Animate (mobile) | 1 Solid |
| 2 Solid | 2 Particles | 2 Liquid |
| 3 Gelatinous | 3 Droplets | 3 Gas |
| 4 Liquid | 4 Bubbles | |
| 5 Film | | |
| 6 Gas | | |

7.2 Object-Stimulus Interaction (circle all appropriate)

| 1 Active Object | 2 Passive Object |
|---|---|
| 1 Cooperative Emission | 1 Reflection |
| 2 Stimulated Emission | 2 Refraction |
| 3 Spontaneous Emission | 3 Scattering |
| | 4 Absorption |
| | 5 Field Perturbation |
| | 6 Indirect |

7.3 Object Information (circle all appropriate)

| 1 Information Transfer | 2 Synoptic Information | 3 Geometric Information |
|---|---|---|
| 1 Communication | 1 Detect Presence | 1 Volumetric |
| 2 Data Telemetry | 2 Identify Features | 2 2-D Image of Surface |
| 3 System Control | 3 Measure Properties | 3 3-D Image of Surface |
| | 4 Determine Motion or Change of Form | 4 3-D Image plus Interior Details |

## 5.2 Determination of Relevant Sensor Technology

### 5.2.1 The TEMPLATE program

A program for examining the data base to determine the relevance of existing sensor technology for specific Coast Guard applications was implemented on a Wang Laboratories Model 2200 Computer System. This computer was selected because of its general availability in Coast Guard facilities. The template matching program (TEMPLATE) has two search modes. In the "regular" mode a search will be implemented using only one descriptor in each taxonomy field. This is used when very specific sensor applications are being considered. In this mode a sensor must match for every descriptor specified in the search morphology, or template, before being found and identified by the program. In the "or" mode several descriptors may be selected in each taxonomy field. This has the effect of permitting a search using several morphologies simultaneously. Sensors will be found and identified by the program which match one or more of the possible morphologic combinations.

An example of a template for a search for oceanographic current meters is shown in Fig. 5.1. Figure 5.2 shows an example of the output from this search. This output is in the "short" form where the data base key number, the sensor title, and its specific use are listed.* A "long" form output is also available which provides the above information plus all of the sensor taxonomy descriptors. Note that all of the sensors identified in Fig. 5.2 are appropriate with the seeming exception of sensor key number 280, which is an electromagnetic ship speed log. This instrument is, however, a type of reverse current

*A complete sensor data base list in short form is included as Appendix B of this report. The long form descriptor list for each sensor is included in Appendices C and D (bound separately).

SENSOR TITLE OR REF. NO. CURRENT METER SEARCH

**5. SENSOR DESCRIPTORS**

**5.1 Function (circle all appropriate)**

| | |
|---|---|
| 1 Navigation | 4 Parametric Measurement |
| 2 Detection | 5 Information Transfer |
| 3 Surveillance (monitoring) | |

**5.1.1 Specific use**

(short description)

**5.2 Sensing Method (Circle 1)**

1 Direct
2 Indirect

(If indirect, show which of descriptors apply to the direct (D) and to the indirect (I) stimuli)

**5.3 Sensor Involvement (Circle 1)**

1 Active  2 Passive

**5.4 Stimulus Used (circle all appropriate)**

| 1 Mechanical | 2 Acoustic | 3 Force Field |
|---|---|---|
| 1 Fluid Motion | 1 Vibration | 1 Gravitation |
| 2 Lin. or Rd. Motion | 2 L.F. Sound | 2 Magnetic |
| 3 Nuclear Particles | 3 M.F. Sound | 3 Electrostatic |
| 4 Heat | 4 H.F. Sound | 4 Electromotive |
| 5 Pressure | | |

| 4 Electromagnetic | 5 Chemical |
|---|---|
| 1 Ionizing waves | 1 Molecular bond |
| 2 Light | 2 Electrochemical |
| 3 Microwaves | 3 Thermochemical |
| 4 Radio waves | |

**5.5 Stimulus Property Sensed (circle all appropriate)**

| Scalar | Vector | Time-Frequency |
|---|---|---|
| 1 off-on | 1 direction | 1 time-interval |
| 2 amplitude | 2 force | 2 period |
| 3 temperature | 3 displacement | 3 frequency |
| 4 volume | 4 velocity | 4 spectrum |
| 5 voltage/ current | 5 acceleration | 5 color |
| 6 chemical change | 6 polarization | |

**5.6 Sensor Availability (Circle 1)**

1 Commercial Product
2 Laboratory Prototype
3 Development Project (available within 3 years)
4 Theoretical Study (availability not known)

**6. ENVIRONMENT DESCRIPTORS**

**6.1 At Sensor (circle all appropriate)**

| | |
|---|---|
| 1 Space | 4 Underwater |
| 2 Air | 5 Bottom |
| 3 Surface | 6 Sub-bottom |

**6.2 At Object (circle all appropriate)**

| | |
|---|---|
| 1 Space | 4 Underwater |
| 2 Air | 5 Bottom |
| 3 Surface | 6 Sub-bottom |

**6.3 Sensor Platform (circle all appropriate)**

| | |
|---|---|
| 1 Fixed | 4 Free fall |
| 2 Mobile, controlled | 5 Hand held |
| 3 Mobile, free | 6 Tethered |

**6.4 Sensor Object Proximity**

1 Contact
2 Near
3 Remote

**7. OBJECT DESCRIPTORS**

**7.1 Nature of Object(s) Sensed (circle all appropriate)**

| 1 Discrete Object (or medium boundary) | 2 Distributed Objects (within medium) | Continuous Medium |
|---|---|---|
| 1 Animate (mobile) | 1 Animate (mobile) | 1 Solid |
| 2 Solid | 2 Particles | 2 Liquid |
| 3 Gelatinous | 3 Droplets | 3 Gas |
| 4 Liquid | 4 Bubbles | |
| 5 Film | | |
| 6 Gas | | |

**7.2 Object-Stimulus Interaction (circle all appropriate)**

| 1 Active Object | 2 Passive Object |
|---|---|
| 1 Cooperative Emission | 1 Reflection |
| 2 Stimulated Emission | 2 Refraction |
| 3 Spontaneous Emission | 3 Scattering |
| | 4 Absorption |
| | 5 Field Perturbation |
| | 6 Indirect |

**7.3 Object Information (circle all appropriate)**

| 1 Information Transfer | 2 Synoptic Information | 3 Geometric Information |
|---|---|---|
| 1 Communication | 1 Detect Presence | 1 Volumetric |
| 2 Data Telemetry | 2 Identify Features | 2 2-D Image of Surface |
| 3 System Control | 3 Measure Properties | 3 3-D Image of Surface |
| | 4 Determine Motion or Change of Form | 4 3-D Image plus Interior Details |

FIG. 5.1. CURRENT METER TEMPLATE.

```
SEARCH OVER THE FOLLOWING
   (IN 'OR' MODE)

1 CURRENT METER SEARCH

---SENSOR DESCRIPTORS---
5.1 FUNCTION
         .PARAMETRIC MEAS.
5.4 STIMULUS USED
     MECHANICAL
         .FLUID MOTION
5.5 STIMULUS PROPERTY SENSED
     SCALAR
         .AMPLITUDE
     VECTOR
         .DIRECTION
         .VELOCITY

---ENVIRONMENT DESCRIPTORS---
6.1 AT SENSOR
         .UNDERWATER
6.2 AT OBJECT
         .UNDERWATER
6.4 SENSOR OBJECT PROXIMITY
         .CONTACT
         .NEAR

---OBJECT DESCRIPTORS---
7.1 NATURE OF OBJECT SENSED
     CONTINUOUS MEDIUM
         .LIQUID(CONT.)
7.3 OBJECT INFORMATION
     SYNOPTIC INFO.
         .MEASURE PROPERTIES
         .MOTION.CHANGE FORM

 1  ( 8 ). KEY IS 8      VERTICAL CURRENT MEASUREMENT
VERTICAL CURRENT METER

 2  ( 9 ). KEY IS 9      CURRENT MEASUREMENT
INCLINOMETER ARRAY

 3  ( 14 ). KEY IS 14      CURRENT AND TURBULENCE MEAS.
3 AXIS CURRENT METER

 4  ( 15 ). KEY IS 15      OCEAN CURRENT MEAS.
EGG MODEL 301 CURRENT METER

 5  ( 38 ). KEY IS 33      CURRENT MESUREMENT
LONG TERM CURRENT MEASUREMENT SYSTEM

 6  ( 44 ). KEY IS 45      WATCH CURRENT METER
ELECTROMAGNETIC CURRENT METER

 7  ( 55 ). KEY IS 53      CURRENT PROFILE MEASUREMENT
FREE FALL ELECTROMAGNETIC CURRENT METER

 8  ( 127 ). KEY IS 121      CURRENT MEASUREMENT
LOW VELOCITY ELECTROSTATIC CURRENT METER

 9  ( 136 ). KEY IS 130      CURRENT METER
ACOUSTIC CURRENT METER

 10  ( 178 ). KEY IS 165      CURRENT METERS
500 SERIES ELECTROMAGNETIC H2O CURRENT MTRS.

 11  ( 179 ). KEY IS 169      FLOW METER
MODEL 201 WATER FLOW MEASUREMENTS

 12  ( 188 ). KEY IS 178      CURRENT VELOCITY
CURRENT METER

 13  ( 228 ). KEY IS 216      CURRENT MEAS.
GEN. OCEANICS RECORDING CURRENT METER

 14  ( 244 ). KEY IS 280      SPEED AND DISTANCE MEAS.
ELECTROMAGNETIC SHIPS LOG SYSTEM

FOUND 14 IN 306 RECORDS
```

FIG. 5.2. CURRENT METER SEARCH RESULTS

meter which moves in a "fixed" medium. Thus, if the electromagnetic principle were not already being used for conventional "fixed" current meters, this application of the morphologic method would have identified a new sensor application.

The general templates developed for the Coast Guard missions shown in Secs. 5.1.1 to 5.1.6 were used to examine the data base for specific sensor systems suitable for the range of applications implied by the associated mission taxonomy. In most cases a group of 20-60 sensors were identified, most of which were either directly applicable to the required need or which employed related or adaptable technology.

The "or" mode search of the data base using a general mission template effectively provides only a general answer about the suitability of available sensor systems. In order to obtain sensor information relating to specific missions, a complete morphological analysis must be conducted wherein each possible morphological combination in the general template is used to search the data base. As illustrated previously in the sandwich example, this often results in a very large number of possible combinations. To make this task manageable (even with the aid of a computer), it was necessary to determine which of the sensor descriptors specified for each general mission template were essential and which were redundant. This was done by using progressively simplified templates in successive searches of the data base. If an important descriptor field were left unspecified the search program would permit a significant increase in the number of nonrelevant sensors identified. Thus after several iterations it was possible to derive a "residual" template for each of the original general mission templates.

These residual templates were then used to form all of the possible sensor morphologies permitted by the remaining taxonomy descriptors.

### 5.2.2 The RESIDUAL program

To facilitate the morphological analysis, the "RESIDUAL" program was devised. This program resulted in a printed form showing all of the possible morphological combinations for a residual sensor taxonomy. As each combination was formed, a complete search of the data base was conducted to determine the number of sensors matching that specific morphology. The matching sensor key numbers were then printed at the end of the line illustrating each morphology. Thus by reviewing the results of the program, it was possible to immediately spot any morphologies which did not evoke a sympathetic response from the data base. These combinations were then analyzed to determine if

1. The morphology had practical meaning
2. If there was a gap in the data base
3. If there was a gap in present technology.

The results of this analysis were then used to develop the recommendations which are the principal output of this study.

## 6. RESULTS OF THE SENSOR MORPHOLOGY ANALYSIS

This section presents a summary of the sensor analysis for each of the residual taxonomies developed for the selected Coast Guard activities. Morphological combinations of particular interest are discussed in detail in a general summary of the analysis for each activity. A discussion of all the results has been included at the end of this section and in the executive summary.

The complete computer output for the RESIDUAL program searches is contained in Appendix A together with the associated detailed analysis sheets. These forms show the mission scenario implied by each morphology combinations, the relevant sensor systems, the number of sensors identified in the data base which match the combinations and an indication of whether or not the identified sensors are relevant to the specific mission. To illustrate the analysis procedure, an example of the computer output and the analysis format is included in the following subsection.

A sensor system is occasionally "found" by the RESIDUAL program which is not seemingly relevant to the application for which the search is being made. Conversely, a relevant sensor system in the data base may be missed. This results from an incorrect classification in the sensor taxonomy in the data base or an insufficient specification of the search morphology to sort out inappropriate sensors. In presenting a summary of the results, any sensor matches which do not seem applicable have been eliminated and any known sensors which are relevant have been added. The nonrelevant sensor systems have been indicated by parenthesis around their key numbers in the program output sheets.

## 6.1 Search and Rescue

As shown in Sec. 5.1.1, two general sensor templates were derived from the mission taxonomy. This was done to be more specific in the sensor morphology, since a search mission may be oceanic in scale and require detection of a distress signal over considerable distance, whereas a rescue mission usually involves a smaller area and requires sensors to distinguish the distressed vessel or survivors from other craft or from the sea surface background.

The general templates were too large to permit convenient analysis, hence the descriptor reduction process described earlier was used to obtain two residual templates. The resulting residual morphological combinations were then analyzed with the assistance of the RESIDUAL program.

### 6.1.1 Search

- Residual Taxonomy and Sensor Descriptors

  Environment at Sensor: Space, Air, Surface, Underwater, Bottom

  Environment at Object: Surface, Bottom

  Sensor-Object Proximity: Remote

  Nature of Object Sensed: Animate (discrete), Solid (discrete), Film

  Object Information: Communication, Detect presence

- Total Number of Combinations: 60 (See Fig. 6.1)

Number of sensors from data base matching one or more combinations: 60

Sensors with highest number of matches:

| Key No. | No. of Matches | Sensor Description or Specific Use |
|---|---|---|
| 132 | 8 (corr.) | Infra Red Detector (nonrelevant matches omitted) |
| 133 | 8 (corr.) | Infra Red Detector (nonrelevant matches omitted) |
| 212 | 6 | Magnetic anomaly detector |
| 95 | 5 | Sea surface marker agents |
| 27 | 4 | Magnetic gradiometer and magnetometer |
| 158 | 4 | Forward Looking Infra-red sensor (FLIR) |
| 207 | 4 | SOFAR system |
| 272 | 4 | Buoy mounted acoustic detection system |
| 279 | 4 (corr.) | Satellite aided emergency beacon detection (Relevant matches added) |

(Specific information on these sensors is available in the Appendices under the sensor key number.)

*Explanation of the Analysis Procedure*

The output of the RESIDUAL program as shown in Fig. 6.1 was analyzed using the following procedure and summarized in the format shown in Fig. 6.2

1. State the Coast Guard mission scenario(s) implied by the specific morphology for each of the reference lines of the computer output. (Column 2 in Fig. 6.2).

2. Analyze the sensor systems found by the program for relevance to the mission application. Determine if the sensors

found are directly applicable, employ closely related technology, or are not relevant. (The total number of sensor systems found in each category are listed under columns "R", "C", and "NR" in Fig. 6.2.)

3. If no sensor systems are found, is this a problem with the data base or is no relevant technology available? Data base problems may be due to incorrect taxonomy assignment of sensors already incorporated (denoted by * in Fig. 6.2), or due to omission of existing sensors from the data base (denoted by ** in Fig. 6.2). The number of sensor systems denoted by * or ** should be considered only as representative since their identification depends on special knowledge of the data base by the analyst.

4. Determine if existing sensor technology seems adequate for the specific mission requirements, if further development or modification of existing technology is indicated, or if new technology must be evolved. Use imagination tempered by the technical requirements. (Columns "E", "D", or "N" in Fig. 6.2.)

5. Select the most appropriate sensor system or development idea and summarize in a brief comment. (Column 3 in Fig. 6.2.)

6. Indicate whether or not this is a mission area where sensor development specifically for Coast Guard needs is recommended ("USCG Dev. Recom." in Fig. 6.2).

7. Provide a brief discussion or recommendation for the sensor development which seems most appropriate for this specific USCG mission. (These recommendations are keyed to the reference line number of Figs. 6.1 and 6.2 and listed on the pages following Fig. 6.2 under "Identified Technological Needs Relevant to this Mission.")

SEARCH OVER THE FOLLOWING
RESIDUAL MORPHOLOGY-SEARCH-1/17/78

---ENVIRONMENT DESCRIPTORS---
6.1 AT SENSOR
.SURFACE
.UNDERWATER
.BOTTOM
6.2 AT OBJECT
.SURFACE
.BOTTOM
6.4 SENSOR OBJECT PROXIMITY:
.REMOTE

---OBJECT DESCRIPTORS---
7.1 NATURE OF OBJECT SENSED
DISCRETE OBJECT
.ANIMATE(DISC.)
.SOLID(DISC.)
.FILM
7.3 OBJECT INFORMATION
INFORMATION TRANSFER
.COMMUNICATION
SYNOPTIC INFO.
.DETECT PRESENCE

**Residual Taxonomy**

**Reference Line No.**

**Specific Morphology**

**Sensor Systems Matching Specific Morphology**

**Nonrelevant Systems**

| | ENV. AT SENSOR | ENV. AT OBJECT | PROXIMITY | OBJECT SENSED | OBJECT INFO. | |
|---|---|---|---|---|---|---|
| 1 | SPACE | SURFACE | REMOTE | ANIMATE(DISC.) | COMMUNICATION | |
| 2 | SPACE | SURFACE | REMOTE | ANIMATE(DISC.) | DETECT PRESENCE | (132) (133) (205) |
| 3 | SPACE | SURFACE | REMOTE | SOLID(DISC.) | COMMUNICATION | |
| 4 | SPACE | SURFACE | REMOTE | SOLID(DISC.) | DETECT PRESENCE | (132) (133) 134 137 279 24 |
| 5 | | | | | | |
| 5 | SPACE | SURFACE | REMOTE | FILM | COMMUNICATION | 95 |
| 6 | SPACE | SURFACE | REMOTE | FILM | DETECT PRESENCE | 95 118 132 133 160 20 |
| 5 283 | | | | | | |
| 7 | SPACE | BOTTOM | REMOTE | ANIMATE(DISC.) | COMMUNICATION | |
| 8 | SPACE | BOTTOM | REMOTE | ANIMATE(DISC.) | DETECT PRESENCE | (132) (133) |
| 9 | SPACE | BOTTOM | REMOTE | SOLID(DISC.) | COMMUNICATION | |
| 10 | SPACE | BOTTOM | REMOTE | SOLID(DISC.) | DETECT PRESENCE | (132) (133) |
| 11 | SPACE | BOTTOM | REMOTE | FILM | COMMUNICATION | |
| 12 | SPACE | BOTTOM | REMOTE | FILM | DETECT PRESENCE | (132) (133) |
| 13 | AIR | SURFACE | REMOTE | ANIMATE(DISC.) | COMMUNICATION | |
| 14 | AIR | SURFACE | REMOTE | ANIMATE(DISC.) | DETECT PRESENCE | (27) (64) 120 132 133 15 |
| 8 182 205 (213) 231 | | | | | | |
| 15 | AIR | SURFACE | REMOTE | SOLID(DISC.) | COMMUNICATION | 230 |
| 16 | AIR | SURFACE | REMOTE | SOLID(DISC.) | DETECT PRESENCE | 27 (64) 120 132 133 15 |
| 8 212 (213) 214 (220) 229 230 231 234 236 245 260 | | | | | | |
| 17 | AIR | SURFACE | REMOTE | FILM | COMMUNICATION | 95 |
| 18 | AIR | SURFACE | REMOTE | FILM | DETECT PRESENCE | 64 90A 90B 90C 90D 95 |
| 107 109 111 132 133 197 205 211 213 222 | | | | | | |
| 19 | AIR | BOTTOM | REMOTE | ANIMATE(DISC.) | COMMUNICATION | |
| 20 | AIR | BOTTOM | REMOTE | ANIMATE(DISC.) | DETECT PRESENCE | 27 (132) (133) |
| 21 | AIR | BOTTOM | REMOTE | SOLID(DISC.) | COMMUNICATION | |
| 22 | AIR | BOTTOM | REMOTE | SOLID(DISC.) | DETECT PRESENCE | 27 (132) (133) 212 215 (23 |
| 0) | | | | | | |
| 23 | AIR | BOTTOM | REMOTE | FILM | COMMUNICATION | |
| 24 | AIR | BOTTOM | REMOTE | FILM | DETECT PRESENCE | 132 133 |
| 25 | SURFACE | SURFACE | REMOTE | ANIMATE(DISC.) | COMMUNICATION | (102) |

FIG. 6.1. EXAMPLE OF "RESIDUAL" PROGRAM OUTRUT FOR RESIDUAL "SEARCH" TEMPLATE

| | | ENV. AT SENSOR | ENV. AT OBJECT | PROXIMITY | OBJECT SENSED | OBJECT INFO. | |
|---|---|---|---|---|---|---|---|
| 25 | 1 | SURFACE | SURFACE | REMOTE | ANIMATE(DISC.) | COMMUNICATION | 102 |
| 26 | 2 | SURFACE | SURFACE | REMOTE | ANIMATE(DISC.) | DETECT PRESENCE | 75 132 133 158 |
| 27 | 3 | SURFACE | SURFACE | REMOTE | SOLID(DISC.) | COMMUNICATION | |
| 28 | 4 | SURFACE | SURFACE | REMOTE | SOLID(DISC.) | DETECT PRESENCE | 93 132 133 158 (212) 23 |
| 4 | 237 | | | | | | |
| 29 | 5 | SURFACE | SURFACE | REMOTE | FILM | COMMUNICATION | |
| 30 | 6 | SURFACE | SURFACE | REMOTE | FILM | DETECT PRESENCE | 132 133 |
| 31 | 7 | SURFACE | BOTTOM | REMOTE | ANIMATE(DISC.) | COMMUNICATION | |
| 32 | 8 | SURFACE | BOTTOM | REMOTE | ANIMATE(DISC.) | DETECT PRESENCE | (132) (133) |
| 33 | 9 | SURFACE | BOTTOM | REMOTE | SOLID(DISC.) | COMMUNICATION | |
| 34 | 10 | SURFACE | BOTTOM | REMOTE | SOLID(DISC.) | DETECT PRESENCE | (132) (133) 212 |
| 35 | 11 | SURFACE | BOTTOM | REMOTE | FILM | COMMUNICATION | |
| 36 | 12 | SURFACE | BOTTOM | REMOTE | FILM | DETECT PRESENCE | (132) (133) |
| 37 | 13 | UNDERWATER | SURFACE | REMOTE | ANIMATE(DISC.) | COMMUNICATION | (108) (207) |
| 38 | 14 | UNDERWATER | SURFACE | REMOTE | ANIMATE(DISC.) | DETECT PRESENCE | (132) (133) (207) 272 |
| 39 | 15 | UNDERWATER | SURFACE | REMOTE | SOLID(DISC.) | COMMUNICATION | 78 84 108 207 |
| 40 | 16 | UNDERWATER | SURFACE | REMOTE | SOLID(DISC.) | DETECT PRESENCE | (132) (133) 207 212 272 23 |
| 7 | | | | | | | |
| 41 | 17 | UNDERWATER | SURFACE | REMOTE | FILM | COMMUNICATION | |
| 42 | 18 | UNDERWATER | SURFACE | REMOTE | FILM | DETECT PRESENCE | (132) (133) |
| 43 | 19 | UNDERWATER | BOTTOM | REMOTE | ANIMATE(DISC.) | COMMUNICATION | |
| 44 | 20 | UNDERWATER | BOTTOM | REMOTE | ANIMATE(DISC.) | DETECT PRESENCE | (132) (133) 142 174 |
| 45 | 21 | UNDERWATER | BOTTOM | REMOTE | SOLID(DISC.) | COMMUNICATION | |
| 46 | 22 | UNDERWATER | BOTTOM | REMOTE | SOLID(DISC.) | DETECT PRESENCE | 51 106 (132) (133) 139 14 |
| 2 | 151 152 153 154 171 174 175A 212 215 277 (252) 268 | | | | | | |
| 48 | 24 | UNDERWATER | BOTTOM | REMOTE | FILM | DETECT PRESENCE | (132) (133) |
| 49 | 25 | BOTTOM | SURFACE | REMOTE | ANIMATE(DISC.) | COMMUNICATION | |
| 50 | 26 | BOTTOM | SURFACE | REMOTE | ANIMATE(DISC.) | DETECT PRESENCE | (132) (133) 272 |
| 51 | 27 | BOTTOM | SURFACE | REMOTE | SOLID(DISC.) | COMMUNICATION | |
| 52 | 28 | BOTTOM | SURFACE | REMOTE | SOLID(DISC.) | DETECT PRESENCE | (132) (133) 272 |
| 53 | 29 | BOTTOM | SURFACE | REMOTE | FILM | COMMUNICATION | |
| 54 | 30 | BOTTOM | SURFACE | REMOTE | FILM | DETECT PRESENCE | (132) (133) |
| 55 | 31 | BOTTOM | BOTTOM | REMOTE | ANIMATE(DISC.) | COMMUNICATION | |
| 56 | 32 | BOTTOM | BOTTOM | REMOTE | ANIMATE(DISC.) | DETECT PRESENCE | (132) (133) |
| 57 | 33 | BOTTOM | BOTTOM | REMOTE | SOLID(DISC.) | COMMUNICATION | |
| 58 | 34 | BOTTOM | BOTTOM | REMOTE | SOLID(DISC.) | DETECT PRESENCE | 106 (132) (133) 252 |
| 59 | 35 | BOTTOM | BOTTOM | REMOTE | FILM | COMMUNICATION | |
| 60 | 36 | BOTTOM | BOTTOM | REMOTE | FILM | DETECT PRESENCE | (132) (133) |

FIG. 6.1. (Cont.)

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 1 | Distress call from swimmer via satellite to rescue station | Radio emergency beacon with sufficient power (see key NR 279) | 1* | | | | ✓ | | ✓ |
| 2 | Detect a swimmer in distress from a satellite | Radio emergency beacon would serve this function also | 1* | | 3 | | ✓ | | ✓ |
| 3 | Distress call from a boat or liferaft via a satellite | Radio emergency beacon (can be larger than swimming type) | 1* | | | | ✓ | | ✓ |
| 4 | Detect a boat in distress from a satellite | Radio emergency beacon (as above) | 1 | 3 | 2 | | ✓ | | ✓ |
| 5 | Use of a dye marker detectable from space to give distress signal | The quantity of dye required may be excessive | 1 | | | ✓ | | | |
| 6 | Detection of dye marker or oil slicks to show distressed vessel position | Matching of dye spectrum and satellite sensor response could improve dye patch detection | 3 | 4 | | | ✓ | | ✓ |
| 7 | Communication of distress signal from diver on bottom via satellite | Swimmer emergency beacon in waterproof case with pop-up buoyancy package | | 1* | | | ✓ | | ✓ |
| 8 | Detection of diver in distress by a satellite | Radio emergency beacon as above | | 1* | 2 | | ✓ | | ✓ |
| 9 | Communication with distressed submersible via satellite | Again a pop-up type of radio beacon is appropriate (see key numbers 279, 234) | | 2* | | | ✓ | | ✓ |
| 10 | Detection of a distressed submersible from a satellite | Radio beacon as above | | 2* | 2 | | ✓ | | ✓ |
| 11 | Detection of a submerged film from space (distress signal) | Not feasible unless film floats to surface - line 5 | | | | | | | |
| 12 | As above | Not feasible | | | 2 | | | | |
| 13 | Distress call from swimmer to aircraft or airship | Radio emergency beacon again appropriate | 1* | | | | ✓ | | ✓ |
| 14 | Detection of distressed swimmer from aircraft or airship | FLIR, IR and visual sensors, radio emergency beacon | 5 | 2 | 3 | ✓ | ✓ | | ✓ |
| 15 | Communication of distress signal to aircraft from ship or boat | VHF radio direction finder and similar equipment | 1 | | | ✓ | | | |
| 16 | Detection of distressed vessel from aircraft or airship | Radar, FLIR, IR, and visual sensors, radio beacons | 14 | | 3 | ✓ | | | |
| 17 | Dye marker from surface vessel to convey distress signal to aircraft | Visual sensors, or sensors using stimulated emission | 1 | | | ✓ | | | |
| 18 | Detection of oil slicks to determine distressed vessel location | Visual sensors, oil pollution sensors | 12 | 4 | | ✓ | | | |
| 19 | Communication from distressed diver to aircraft | Pop-up radio beacon (similar to line 7) | | 1* | | | ✓ | | ✓ |
| 20 | Detection of distressed diver from aircraft | Radio beacon (as above) | | 1* | 2 | | ✓ | | ✓ |
| 21 | Communication from distressed submersible to aircraft | Radio beacon (as above) (similar to line 9) | 1* | | | ✓ | | | |
| 22 | Detection of distressed submersible from aircraft | Magnetic anomaly sensors, radio emergency beacons (pop-up) | 4* | | 3 | ✓ | | | |
| 23 | Dye marker distress signal from submersible on bottom for aircraft detection | May be effective in pop-up capsule (line 17) | | 1* | | | ✓ | | ✓ |
| 24 | Dye marker to show general location of distressed submersible to aircraft | As above, may be used with specific spectrum sensors | | 2 | | | ✓ | | ✓ |
| 25 | Communication from distressed swimmer to search vessel | Radio beacon for swimmers | | | 1 | | ✓ | | ✓ |
| 26 | Detection of distressed swimmer from search vessel | FLIR, IR and visual sensors, radio beacon | 3 | 1 | | ✓ | | | |
| 27 | Communication from distressed vessel to search vessel or shore station | Emergency radio beacon, standard radio distress call | 2* | | | ✓ | | | |
| 28 | Detect distressed vessel from search vessel | Radar, FLIR, and visual sensors, radio beacon | 4 | 2 | 1 | ✓ | | | |
| 29 | Dye marker distress signal from surface craft to search vessel | May be used to improve detectability but not as effective as in air search | 1* | | | ✓ | | | |
| 30 | Dye marker as above | As above | 1* | 2 | | ✓ | | | |
| 31 | Communication from distressed diver to surface vessel | Diver communication equipment can be used (see key numbers 181, 198 A, B, 239) | 5* | | | ✓ | | | |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

Sensors Found: R - Relevant, C - Close, NR - Not Relevant
Indicated Technology: E - Exists, D - Development Needed, N - New Tech. Req.

FIG. 6.2. MORPHOLOGICAL ANALYSIS — SEARCH (Example of Analysis Format)

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 32 | Detection of distressed diver by surface vessel | Pingers, pinger locators and scanning sonars can be used, also pop-up radio beacon (see key numbers 142, 153, 174, 277) | 4* | 1* | 2 | ✓ | ✓ | | ✓ |
| 33 | Communication from distressed submersible to surface vessel or shore station | Underwater telephone, pop-up radio beacon (see key numbers 181, 183, 234) | 3* | | | ✓ | | | |
| 34 | Detection of distressed submersible by surface vessel | Magnetic anomaly detection, pop-up, radio emergency beacon | 4* | | 2 | ✓ | | | |
| 35 | Dye marker to show location of distressed submersible to surface vessel | Pop-up capsule may be used, probably not as effective as well as air search (line 23) | | 1* | | | ✓ | | |
| 36 | Dye marker to aid detection of submersible (as above) | As above | | 1* | 2 | | ✓ | | |
| 37 | Communication from distressed swimmer to submersible or underwater sensor | Not practical for search scenarios – rescue scenario more feasible. Modificaiton of diver comm. equipment possible solution | | | 2 | | ✓ | | |
| 38 | Detection of distressed swimmer by submersible | As above, distress signal pinger a possible solution | 1 | | 3 | ✓ | ✓ | | |
| 39 | Communication from distressed surface vessel to submersible or underwater sensor | Underwater acoustic sensors, electric field sensors (limited range), underwater telephone | 4 | | | ✓ | | | |
| 40 | Detection of distressed surface vessel by submersible or underwater search sensor station | Underwater acoustic sensors (SOFAR), distress pinger, magnetic meter (see line 37) | 3 | 1 | 2 | ✓ | | | |
| 41 | Underwater detection of surface distress dye marker | Not practical | 1* | | | ✓ | | | |
| 42 | As above | As above | 1* | | 2 | ✓ | | | |
| 43 | Communication of distressed diver with submersible, underwater habitat, or another diver | Diver communication equipment can be used (see key numbers 2, 181, 198A, 198B, 239) | 5* | | | ✓ | | | |
| 44 | Detection of distressed diver by submersible | High resolution sonar, distress pinger and locator gear | 2 | | 2 | ✓ | | | |
| 45 | Communication between distressed submersible and search sub. | Underwater telephone (see key numbers 60, 67, 181, 183) | 4* | | | ✓ | | | |
| 46 | Detection of a distressed submersible by a search sub. | High resolution sonar, magnetometers, distress pinger | 8 | 4 | 3 | ✓ | | | |
| 47 | (Line omitted by computer) see below | See below | | 1* | | ✓ | | | |
| 48 | Detection of a dye marker from a distressed submersible by a search sub. | Not practical | | 1* | 2 | ✓ | | | |
| 49 | Communication from a distressed swimmer via a sensor system on the bottom | Not practical, diver communication equipment would work | 4* | | | ✓ | | | |
| 50 | Detection of distressed swimmer by bottom mounted sensor system | Not practical, acoustic detection systems together with a distress pinger would work | 1 | | 2 | ✓ | | | |
| 51 | Communication of distressed vessel via sensor system at bottom | Not practical, underwater telephone appropriate | 1* | | | ✓ | | | |
| 52 | Detection of distressed vessel by bottom-mounted sensor system | SOFAR signal system, distress pinger | 1 | | 2 | ✓ | | | |
| 53 | Dye marker distress signal from surface vessel detected by bottom sensor | Not practical | | 1* | | ✓ | | | |
| 54 | As above | As Above | | 1* | 2 | ✓ | | | |
| 55 | Communication between distressed diver and underwater habitat, search submersible or another diver | Similar to line 43 | 5* | | | ✓ | | | |
| 56 | Detection of distressed diver by bottom sensor system, mobile or stationary | Bottom crawling vehicle with precision sonar (see key number 174) or distress pinger and locator system (key number 153) | 2* | | 2 | ✓ | | | |
| 57 | Communication from distressed submersible via bottom sensor system | Underwater telephone, electric communication system (see key numbers 183, 102) | 2* | | | ✓ | | | |
| 58 | Detection of distressed submersible by bottom sensor system, mobile or stationary | Precision sonar and magnetometer on moving vehicle, distress pinger, SOFAR and directional acoustic sensor system | 1 | 1 | 2 | ✓ | | | |
| 59 | Dye marker or chemical distress signal for submersible, sensed at bottom by vehicle or stationary sensor | May have limited effectiveness down current from distress site, chemical agent and sensors more effective than dye | | 1* | | ✓ | | | |
| 60 | As above | As above (see key numbers 217, 226, 227) | 3* | | 2 | ✓ | | | |

FIG. 6.2. (Cont.)

- Identified Technological Needs Relevant to this Mission (from Fig. 6.2)

| Ref. Line No. | Sensor Requirement |
|---|---|
| 1-2 | Further development of radio emergency beacons to enable signals to be detected or relayed by satellite to nearest rescue equipment base. Miniaturization of equipment would permit using the beacon as part of lifejacket aid package. |
| 3-4 | As above except the radio beacon package for lifeboats or liferafts could be larger and thus have more available output power than that designed for swimmer use. |
| 6 | By matching the light spectrum of distress dye markers and satellite color sensors it should be possible to improve the effectiveness of satellites in resolving small color anomalies on the ocean surface. Thus a practically sized dye package could be used to mark a distress site. |
| 7-8 | If a radio emergency beacon is developed which permits signals to be detected or relayed via satellites, this unit could be designed to fit into a package with deployable buoyancy. Thus a diver in distress could activate the buoyancy bag and pop the radio package to the surface. A tether would be used to keep the beacon in position. |
| 9-10 | Present emergency radio beacons, designed to be sent up to the surface from a distressed submersible, should be improved to enable the distress signal to be relayed via a satellite. This would be particularly applicable to larger submersibles which operate independently without a "mother" ship. |

| Ref. Line No. | Sensor Requirement |
|---|---|
| 13-14 | The radio emergency beacon for swimmer use, discussed under lines 1-2 above, should be capable of being received by aircraft in addition to satellites. This would facilitate locating the swimmer quickly after the distress signal was received. |
| 19-20 | The comment above also applies to the distressed diver radio beacon discussed under lines 7-8. |
| 23-24 | A dye marker could be used as a distress signal from a submersible to aid aircraft search. The dye injection could be effected by a pop-up capsule which would release the material upon reaching the surface. A quasi-continuous injection of dye (a series of capsules) should be used to prevent the mark from drifting away from the distress location. |
| 25 | The swimmer radio beacon discussed under lines 1-2 could also be used to aid surface vessel search if the search vessel were equipped with appropriate direction finding receivers. |
| 32 | The above comment also applies to the diver pop-up beacon discussed under lines 7-8. |

### 6.1.2 Rescue

- Residual Taxonomy

  Environment at Sensor: Air, Surface, Underwater

  Environment at Object: Surface, Bottom

  Sensor Platform: Mobile-controlled

  Sensor Object Proximity: Remote

Nature of Object: Animate (discrete), Solid (discrete)

Object Information: Communication, System Control, Identify Features

- Total number of combinations: 36
- Number of sensors from data base matching one or more combinations: 32
- Sensors with highest number of matches

| Key No. | No. of Matches | Sensor Description or Specific Use |
|---|---|---|
| 94 | 4 | Ocean Photography (from aircraft) |
| 158 | 4 | Forward Looking Infra Red Sensor (FLIR) |
| 64 | 2 | Multispectral Photographic Sensing |
| 108 | 2 | Extra-Low Frequency Submersible Comm. |
| 114 | 2 | Underwater Optical Imaging |
| 120 | 2 | Infra Red and TV Sensors |
| 174 | 2 | High-Resolution Scanning Sonar |
| 213 | 2 | Aerial Photography |
| 231 | 2 | Synthetic Aperture Radar |
| 236 | 2 | VHF Automatic Radio Direction Finder |

- Identified Technological Needs Relevant to the Mission*

| Ref. Line No. | Sensor Requirement |
|---|---|
| 2 | Emergency radio rescue beacon for swimmer use (discussed in lines 1-2 and 13-14 of Search Morphology Analysis) |

*See Appendix A for complete analysis.

| Ref. Line No. | Sensor Requirement |
| --- | --- |
| 3 | Location of distressed swimmers could be aided by improving their visual and radar reflectivity. Methods of doing this should be developed. One possible scheme would employ an inflatable radar reflector which is fluorescent orange in color. Inflation could be by $CO_2$ cartridge or by a sea-water activated gas generator. If a gas such as hydrogen were used, the reflector could be made to rise above the water on a tether and thus be considerably more detectable both visually and by radar. |
| 8 | Pop-up type of emergency radio beacon for divers as discussed under Search Analysis, lines 7-8, 13-14 and 19-20. |
| 10-12 | Pop-up emergency radio beacon for submersibles. Discussed under Search Analysis, lines 9-10 |
| 13-15 | A directional microphone system would be useful on rescue craft for improving the detectability of shouts or whistle signals from swimmers. This would also aid in determining their bearing. |
| 19-20 | An emergency pinger on a distressed diver and a directional hydrophone on the rescue vessel would help position the rescue vessel so that a team of rescue divers could reach the diver in trouble. The rescue divers could be aided by a powered sled that was able to home on the distressed diver's pinger. This vehicle would then be used to return the diver to the surface. Alternatively, a lock-out rescue submersible could be developed for this application. |

| Ref. Line No. | Sensor Requirement |
|---|---|
| 22 | Present underwater telephone performance is degraded by multipath transmission in near-bottom and shallow water applications. Development of multipath and reverberation interference reduction techniques and equipment would provide better communication systems for use in underwater rescue applications. |
| 23 | An automatically controlled surface-launched submersible rescue vehicle can home on the location of a distressed submersible using the emergency beacon signal (as in lines 19-20). |
| 25-27 | In these lines the implied scenario suggests the use of a submersible to rescue personnel from the surface. Normally this would not have any advantage over rescue using surface craft; however, in severe weather conditions, if the rescue could be accomplished without requiring the submersible to surface, the risk to personnel would be reduced. Some type of rescue capsule could be devised which could be floated up to the vicinity of the surface swimmer. The swimmer would then enter the capsule and be winched down to the submersible. An airlock would permit transfer to the submersible.<br><br>It is necessary to provide a sensor system for the submersible which can detect the swimmer in the prescence of wave noise and enable the submersible to maneuver to the proper location. If the swimmer has an emergency pinger, this can be done with existing "ping-pointer" receivers. However, if the distressed swimmer has no rescue assistance devices, his body |

| Ref. Line No. | Sensor Requirement |
|---|---|
| | presents a very poor target for sonar because of the high background clutter due to the rough sea surface. Development of specialized sonars, probably of the doppler type, will be ncessary. |
| 28-30 | In this combination a rescue of a surface craft by a submersible is implied. The comments under lines 25-27, above, apply. Location of the surface craft by the submersible would not be as difficult in this case since, presumably, the underwater portion of the surface craft's hull would present a better sonar target. However, an inflatable life raft would be a difficult target. |
| 34 | If the bottom terrain around a distressed submersible is quite rough, ELF EM radiation may provide a better communication/location signal than underwater sound. This radiation would be aided by the proximity to the bottom and would not be scattered and attenuated by the rough bottom terrain. |

### 6.2 Oil Spill Detection and Classification

The procedure followed was similar to that used for search and rescue.

#### 6.2.1 Oil spill detection

- Residual Taxonomy

  Environment at Sensor: Space, Air

  Environment at Object: Surface

Sensor Platform: Mobile, controlled

Sensor-Object Proximity: Remote

Nature of the Object: Liquid, Film

Object Stimulus Interaction: Stimulated Emission, Spontaneous Emission, Reflection, Scattering, Absorption

Object Information: Detect Presence, Identify Features, 2-D Surface Image

- Total number of combinations: 60
- Number of Sensors from Data Base Matching One or More Combinations: 38
- Sensors with highest number of matches

| Key No. | No. of Matches | Sensor Descriptor or Specific Use |
|---|---|---|
| 160 | 18 | Multispectral Scanner (Satellite) |
| 90D | 12 | Side-looking Radar (Aircraft) |
| 118 | 6 | ERTS-1 Satellite Sensor System |
| 90A | 6 | IR and UV Line Scanner (Aircraft) |
| 90B | 6 | Low-Light TV (Aircraft) |
| 90C | 6 | Microwave Imager (Aircraft) |
| 213 | 6 | Aerial Photography |

- Identified Technological Needs Relevant to this Mission:*

a. Systems to collect spatial imagery at various wavelengths have been developed. Synthetic Aperture Radar (SAR) systems are being driven by other needs but can be adapted to this mission.

*See Appendix A for complete analysis.

b. Choice of optical wavelength/radar frequency to optimize oil detection needs to be investigated.

c. Data reduction procedures need to be developed to allow more immediate access to the information of interest. (Present techniques tend to require several days to several weeks. Oil spill detection needed in less than a day from data collection.)

### 6.2.2 Oil spill classification

- Residual Taxonomy

  Environment at Sensor: Air, Surface, Underwater

  Environment at Object: Surface, Underwater, Bottom

  Object-Stimulus Interaction: Stimulated Emission, Spontaneous Emission, Reflection, Refraction, Scattering, Absorption

  Object Information: Measure Properties

- Total Number of Combinations: 54
- Total Number of Sensors from Data Base Matching One or More Combinations: 99
- Sensors with highest number of matches

| Key No. | No. of Matches | Sensor Descriptor or Specific Use |
|---|---|---|
| 230 | 6 | Multispectral Scanner (Aircraft) |
| 180 | 4 | Laser Backscatter |
| 204 | 4 | Gas Chromatograph |
| 284 | 3 | Xray Fluorescence |

• Identified Technological Needs Relevant to this Mission

a. Development of an integrated, multisensor system to provide all the classification information needed to deal with the spill.

b. Technique for collecting samples by the airborne platform (presumably a CG patrol aircraft).

### 6.3 Offshore Law Enforcement

A single residual morphology was developed for this activity. This morphology is directed at missions concerning 200-mile fishing zone enforcement, monitoring of underwater mining activity, detection of clandestine boat landings and detection of illegal submersible operations. It is quite possible that submersibles will be increasingly employed in illegal activities involving materials of high economic value. For example, if shellfish prices continue to increase, it may be economically feasible to harvest them clandestinely by submersible. Presumably the submersibles could be tended by a factory ship lying just outside the 200-mile boundary.

Sensor technology for use in detecting and apprehending drug smugglers was not directly included in this study since it is primarily an in-air sensor application. Hence a taxonomy for this activity was not developed. A future augmentation of the data base could include more of the appropriate sensor technology if desired.

*See Appendix A for complete analysis.

### 6.3.1 Offshore law enforcement

- Residual Taxonomy

  Environment at Sensor: Air, Surface, Underwater, Bottom

  Environment at Object: Surface, Underwater

  Sensor-Object Proximity: Remote

  Nature of Object: Solid

  Object-Stimulus Interaction: Spontaneous Emission, Reflection, Field Perturbation

  Object Information: Detect Presence, Identify Features

- Total Number of Combinations: 48

- Number of Sensors from Data Base Matching One or More Combinations: 62

- Sensors with highest number of matches:

| Key No. | No. of Matches | Sensor Description or Specific Use |
|---|---|---|
| 212 | 13 | Magnetic Anomaly Detection |
| 132 | 5(corr) | Infra-Red Detection |
| 272 | 5 | Acoustic Detection System for Buoy Application |
| 237 | 5 | Submersible Flasher Beacon |
| 64 | 4 | Remote Oceanographic Sensing |

| Key No. | No. of Matches | Sensor Description or Specific Use |
|---|---|---|
| 94 | 4 | Ocean Photography |
| 120 | 4 | Infra-Red TV |
| 158 | 4 | Forward Looking Infra-Red Detector (FLIR) |
| 215 | 4 | Magnetic Anomaly Detector, Underwater |
| 275 | 4 | Moored Underwater Surveillance System |
| 252 | 4 | Ferrous Material Intrusion Detector |

- Identified Technological Needs Relevant to this Mission

| Ref. Line No. | Sensor Requirement |
|---|---|
| 4 | Further development of high resolution synthetic aperture radar for surface ship surveillance |
| 12 | Develop technology for a 2-D image of the earth's magnetic field strength to detect a moving anomaly representing a submersible among natural anomalies of comparable or greater strength. |
| 17 | Development of over the horizon, low-frequency radars using either backward or forward scattering (bistatic) to detect ships at considerable distance from a remote (probably land-based) site. |
| 41 | Develop a system using bottom-laid (or buried) cables to produce a magnetic barrier-type detection system to detect clandestine boat operations along remote shorelines. |

*See Appendix A for complete analysis.

| Ref. Line No. | Sensor Requirement |
|---|---|
| 42 | As above plus use of pulsed field to determine the size of detected target. |
| 47, 48 | As in lines 41, 42 except for application in deeper water and harbor entrances against submersible. |

### 6.4 Ice Operations

Two residual taxonomies for ice measurements and ice-breaking were developed to provide specific focal areas for the sensor technology analysis.

#### 6.4.1 Ice measurement and mapping

*Mission Description*

Determine ice coverage, type, and thickness to yield synoptic maps on different scales. (1) Global scale, encompassing entire extent of Coast Guard responsibility, to provide strategic summary of ice conditions and their evolution in time; (2) Major water-system scale, such as Great Lakes or Northwest Passage to permit coordinated planning of ice-breaking operations; (3) Intermediate scale, such as critical areas along navigable waterways, to insure conditions are known and areas kept open during navigable seasons; (4) Small scale, in vicinity of individual icebreakers (covered more explicitly under Helicopter-Aided Icebreaking) or arctic installations (oil platforms)

- Residual Taxonomy and Sensor Descriptors

  Stimulus Used: H.F. Sound, Magnetic Field, Light, Microwaves

  Environment at Sensor: Space, Air, Surface, Underwater

  Environment at Object: Surface

  Nature of Object Sensed: Solid (discrete)

  Object Information: Detect presence, identify features, measure properties, 2-D surface image

- Total Number of Combinations: 64

- Total Number of sensors from data base matching one or more combinations: 29

- Sensors with highest number of matches:

| Key No. | No. of Matches | Sensor Description or Specific Use |
|---|---|---|
| 132 | 6 (corr.) | Infra Red Detectors (photoconductive) |
| 133 | 6 (corr.) | Infra Red Detectors (pyroelectric) |
| 158 | 6 | Forward looking IR sensors – low light level |
| 212* | (6)† | Magnetometer – anomaly detection |
| 231 | 6 (3) | Synthetic aperture radar – ship search |
| 245 | 6 | Synthetic aperture radar – global search |
| 94 | 4 | Improved photographic films for oceanic use |
| 64 | 3 | Multispectral photographic sensing |

*Not relevant to this mission.

†Numbers in parentheses are the irrelevant matches.

| Key No. | No. of Matches | Sensor Description or Specific Use |
|---|---|---|
| 120 | 3 | Evaluation of IR and TV sensors |
| 213 | 3 | Aerial photographic system |
| 214 | 3 | High resolution radar |
| 219 | (3) | Magnetic field measurement (superconducting) |
| 229 | 3 | X-L band synthetic aperture radar |
| 237 | (3) | Submersible flasher beacon |

- Identified Technological Needs Relevant to this Mission*

| Ref. Line No. | Sensor Requirement |
|---|---|
| *Navigable Narrows* | |
| 1-4<br>13 | Active sonar array permanently installed at narrows in important navigable passages maps ice coverage, synoptically. Information, including 2-dimensional map, relayed by microwave to central processing station for that geographic region either directly or via satellite. The array could be supplemented by passive components measuring ambient noise due to the ice. Different ambient noise spectral shapes and/or levels may be correlated with the type of ice. |
| 41-43<br>57-58 | Above water installation at the same narrows of scanning IR, laser, or microwave systems monitors above-water ice shapes, notes occurrence of icebergs. Processed information forwarded by same data link as for sonar. |

*See Appendix A for detailed analysis.

| Ref. Line No. | Sensor Requirement |
|---|---|
| *Ice Stations (e.g., research installations, oil platforms)* | |
| 10-11 | Surface vehicle (e.g., snowmobile) makes detailed survey of ice thickness acoustically prior to establishing an ice station or surveys area around an ice-bound oil platform to determine best path for approaching or departing vessel. Acoustic data supplemented with detailed visual observation of ice type. Vehicle's position monitored and possibly controlled via radio link to the station. |
| 41-43 | Scanning IR system provides continuous readout of local ice conditions (type, coverage). |
| *"Global" Survey* | |
| 33-36<br>49-52 | Satellite-mounted detectors determine ice presence and coverage with sufficient data rate to permit map generation at ground installation. Rapid data processing for ice movement coverage. Microwave data transfer. Sensor systems appropriate for consideration in such a configuration include optical devices using high resolution lenses and scanning infrared systems which can determine ice thickness. Radar can be used for somewhat coarser mapping. Much of the system exists and only requires specific implementation. |
| *Major-water System Surveys* | |
| | Much of the information needed for major water systems can be generated from a "global" system such as mentioned above. Details can be supplemented with aerial surveys. Aerial photography |

| Ref. Line No. | Sensor Requirement |
|---|---|
| 37-40 | can provide detail on ice occurrence, coverage and type. Infrared detectors and photography can be used during days where cloud cover prevents normal photographic methods. IR devices which can scan both spatially and spectrally increase the probability of identifying ice type on such poor visibility |
| 53-56 | days. Microwave emission from ice can be used to yield maps of ice coverage when visibility is poor, and radar can be used to measure ice thickness. |
| 21-24 | Eddy current losses also provide a means to determine thickness. |

*Understanding Ice-Breaking Dynamics*

| Ref. Line No. | Sensor Requirement |
|---|---|
| | Furtherance of such understanding might enhance ice-breaking efficiency. An important aspect is a knowledge of the range of underwater contours one might encounter. Such maps and three-dimensional displays could be generated from data gathered by |
| 16 | submarine-mounted sensor systems including high- |
| 45-48 | frequency acoustic, and photographic types. |

### 6.4.2 Helicopter-aided ice breaking*

*Mission Description*

Determine local ice type and thickness so best ice breaking path can be selected. Helicopter, based on icebreaker, available to assist in this local survey. Task could occur on two scales: (1) individual icebreaker clearing a single path; (2) group of icebreakers working together to clear a larger region.

*This mission was also considered to include other remote instrument platforms such as tethered balloons and remote-control vehicles.

- Residual Taxonomy and Sensor Descriptors

  Stimulus Used: H.F. Sound, magnetic field, light, microwaves

  Environment at Sensor: Air, surface, underwater

  Environment at Object: Surface, underwater

  Sensor platform: Mobile controlled

  Nature of Object Sensed: Solid (discrete)

  Object Information: Detect presence, measure properties, 2-D surface image

- Total Number of Combinations: 72

- Total Number of sensors from data base matching one or more combinations: 47

- Sensors with highest number of matches:

| Key No. | No. of Matches | Sensor Description or Specific Use |
|---|---|---|
| 212 | (12)* | Magnetic anomaly detector |
| 219 | (6)* | Magnetic field measurement – super-conductive |
| 64 | (4) | Multispectral photographic sensing |
| 94 | (4) | Improved photographic films for oceanic use |
| 158 | (4)* | Forward-looking IR sensors – low light levels |
| 215 | 4 | Magnetic anomaly detector |
| 230 | 4 | Multispectral scanner for earth resources |
| 231 | 4 | Synthetic aperture radar – ship search |
| 91 | 2 | FM radar to measure ice thickness |
| 92 | 2 | Ice Identification System |

| Key No. | No. of Matches | Sensor Description or Specific Use |
|---|---|---|
| 101 | 2 | Obstacle avoidance sonar |
| 120 | 2 | Evaluation of IR and TV sensors |
| 142 | 2 | Low-frequency scanning sonar |
| 152 | 2 | Scanning sonar for submersibles |
| 174 | 2 | Underwater location and navigation – acoustic |
| 175A | (2) | Well reentry sonar and TV |
| 202 | 2 | IR determination of ice thickness; imagery |
| 213 | (2)† | Aerial camera |
| 214 | 2 | High resolution radar |
| 220 | 2 | Electromagnetic ice profiler |
| 229 | 2 | Synthetic aperture radar for sea ice and icebergs |
| 238 | (2)† | Range-gated photographic system |
| 241 | 2 | Underwater TV transmission |
| 245 | 2 | Synthetic aperture radar – global search |
| 267 | 2 | IR detection of surface |
| 273 | 2 | Underwater laser radar |

*Various magnetic anomaly detectors were selected when "magnetic" force field was chosen for the template to yield the eddy-current device. Such magnetic detectors are felt to be irrelevant.

†Photographic systems deemed inappropriate for quick-response ice-breaking operations.

• Identified Technological Needs Relevant to this Mission*

| Ref. Line No. | Sensor Requirement |
|---|---|

*Icebreaker alone*

Ice presence and above-water shape determined from
43, 45 icebreaker using radar or alternatively infrared
61, 63 scanners. These are particularly relevant in low
visibility or at night. Detection acoustically of underwater shape and depth of ice from the vessel should be actively considered, although there are significant problems in implementation; a bow-mounted sonar is probably impractical and a variable-depth sonar lowered on a cable may be unacceptable.

*Helicopter Assisting Icebreaker*

The helicopter can be used to assist in far more extensive ways than just visual observations radio-relayed to the vessel. Airborne acoustic signals
1, 3 from the helicopter could determine ice presence
4-6 in low visibility and active sonar lowered by cable
from the helicopter through open patches of water could examine underwater portions of the ice. Ice thickness could be determined using the eddy-
19, 20 current device mounted on the helicopter.
37-39 Infrared scanners on the helicopter can not only
determine ice presence and shape but actual ice thickness. They probably have much finer spatial resolution than the magnetic device.
55-57 Finally radar can be used to determine ice presence
and thickness, giving local maps. Passive devices

*See Appendix A for complete analysis.

| Ref. Line No. | Sensor Requirement |
|---|---|
| | responsive to microwave emission can determine presence. |
| | There is obviously an overlap in function in these devices so that not all are needed. Presumably the choice might be made based on consideration of the helicopter's total mission. Other helicopter uses are found below. |

*Surface Vehicle and Helicopter Assisting Icebreaker*

| | |
|---|---|
| | A small, unmanned surface vehicle could precede the icebreaker, guided by the helicopter, when ice cover permitted such travel. It could be outfitted with a variety of sensors such as low- |
| 8 | light-level TV camera, IR scanners, and acoustic probe to force against the ice for ultrasonic thickness determination. A radio link to the vessel and helicopter would provide control and data relaying. The vehicle would be launched and recovered from the helicopter. |
| | Such a system would be less complicated than the underwater vehicle described below, but also less versatile since it would be limited to those ice conditions where the vehicle could actually propel itself over the ice. |

*Underwater Vehicle and Helicopter Assisting Icebreaker*

An unmanned underwater vehicle, preferably untethered, precedes the icebreaker and is controlled by it. The icebreaker vectors both the underwater craft and the helicopter, often to the same

| Ref. Line No. | Sensor Requirement |
|---|---|
| | point, so that a control center on the icebreaker receives a simultaneous picture of below-and above-water ice conditions. |
| | The helicopter could be outfitted with some of the airborne devices discussed above. |
| 52, 54<br>16-18 | The submerged craft could have underwater TV and laser radar; also various sonar devices including side-scan for mapping and upward-looking sonar for delineating underwater contours and thickness. |
| 62 | Deployable, expendable sensors could also be used to measure ice parameters at some distance from an icebreaker. These could be similar to sonobuoys in configuration and be launched either from a helicopter or by a rocket from an icebreaker. |

*Balloon-Platform Assisting Icebreakers*

| Ref. Line No. | Sensor Requirement |
|---|---|
| | A helicopter could be either replaced or supplemented in poor flying conditions by a balloon tethered to the vessel and containing a platform on which an |
| 1,3,19,20<br>37-39,55-57 | instrumental suite is mounted. This could contain an appropriate mix of acoustic, magnetic, light, and microwave sensing devices. |

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MORPHOLOGICAL ANALYSIS OF UNDERWATER SENSING FOR COAST GUARD AP--ETC(U)

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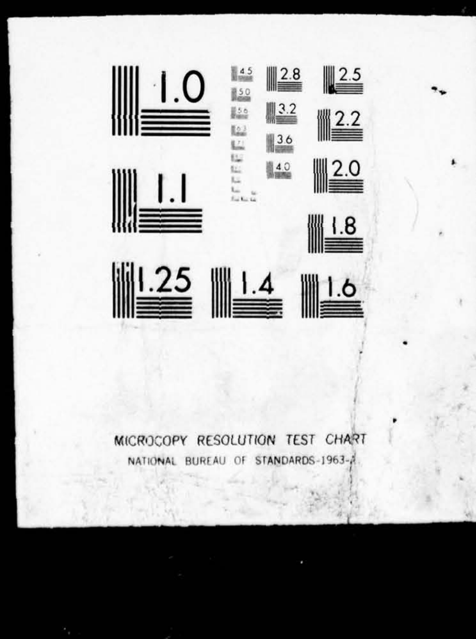

## 6.5 Port Safety and Security

The sensor morphology analysis was directed primarily at detecting water based sabotage and terrorist activity since other missions in this area would imply primarily in-air sensing requirements.

### 6.5.1 Port Anti-Sabotage and Terrorism

- Residual Taxonomy of Sensor Systems

  Function: Detection, Surveillance

  Environment at Object: Surface, Underwater, Bottom, Sub-bottom

  Nature of Object: Animate (discrete), Solid (discrete)

  Object Information: Detect Presence, Identify Features, 2-D Image

- Total number of combinations: 48

- Number of sensors from data base matching one or more combinations: 104

- Sensors with highest number of matches: (12 for each)

| Key No. | Sensor Specific Use |
|---|---|
| 64 | Remote photographic sensing |
| 101 | Diver vehicle sonar |
| 120 | Infra red and TV sensor systems |
| 152 | Navigation sonar for submersibles |
| 158 | Low light level sensor (FLIR) |
| 174 | High resolution scanning sonar |
| 231 | Synthetic aperture radar |
| 266 | High definition swimmer detection sonar |

• Identified Technological Needs Relevant to Mission*

| Ref. Line No. | Sensor Requirement |
|---|---|
| 8 | Further development of swimmer detection sonar is required. Bistatic (shadow-detecting) sonar seems particularly promising. Refinement of doppler-type sonar is necessary to improve detection range and minimize false alarms. |
| 14 | Above comments apply. In addition, special transducer design and placement is required for detecting swimmers near the bottom. Minimizing false alarms from bottom fish is necessary. |
| 32-33 | A concept similar to that used for acoustic fish counters is attractive for use as an installed swimmer (and submersible) detector fence at harbor entrances or pier-heads. In this application active, upward directed sonar transducers are placed along the bottom in a row so that their beam patterns overlap. |
| 37 | Same application as in lines 32-33. In this case the acoustic transducers may have to be shallowly buried to escape detection by bottom swimmers. |
| 40 | Electrical cables may be placed along the bottom to form magnetic detection loops for conductive objects passing near them. They can be oriented to form barriers across harbor entrances and channels. |

*See Appendix A for detailed analysis.

## 6.6 Aids to Navigation

Because of the nature of the data base, the morphological analysis was oriented toward underwater sensors for navigational assistance.

### 6.6.1 Aids to Navigation

- Residual Taxonomy

  Stimulus Used: H.F. Sound, Magnetic Field, Radio Waves

  Environment at Sensor: Surface, Underwater
  Environment at Object: Surface, Underwater, Bottom
  Sensor Platform: Mobile Controlled
  Sensor-Object Proximity: Remote

  Nature of Object: Solid (discrete)
  Object-Stimulus Interaction: Cooperative emission, Stimulated emission, Spontaneous emission, Reflection

- Total number of combinations possible: 72

- Total number matching sensors identified: 32

- Sensors with highest number of matches:

| Key No. | No. of Matches | Sensor Descriptor or Specific Use |
|---|---|---|
| 212 | 6 | Magnetic Anomaly Detector |
| 175 A | 4 | Combined Sonar/TV for Well Re-entry |
| 140 | 2 | Doppler Speed Log |
| 142 | 2 | Scanning Sonar and Recorder |
| 152 | 2 | Scanning Sonar for Submersibles |
| 153 | 2 | Dual Frequency Transponder |
| 173 | 2 | Doppler Speed and Distance Log |

| Key No. | No. of Matches | Sensor Descriptor or Specific Use |
|---|---|---|
| 174 | 2 | High Resolution Scanning Sonar |
| 177 | 2 | Solid State Compass |
| 208 | 2 | Radiated Noise Measurement System |
| 215 | 2 | Magnetic Anomaly Detector |
| 277 | 2 | Acoustic Transponder |

- Identified Technological Needs Relevant to Mission*

| Ref. Line No. | Comments on Recommended Developments |
|---|---|
| 21 | Bottom-mounted acoustic navaids such as beacons or transponders would be useful in areas where seasonal ice cover creates problems with buoy-mounted surface aids. They would also be useful in relocating the correct position for a surface navaid anchor after the aid had been lost or moved due to ice or storm action. |
| 24 | The above comment applies. In this case passive reflectors would be used to serve as the underwater markers. These could be designed to provide an effectively large reflective cross section at the interrogation or search sonar frequency. |
| 69 | ELF EM waves may be useful for a submersible navaid system in rough bottom terrain areas where acoustic systems are not effective. The range achieved would depend on the dielectric properties of the bottom material. The frequencies employed must be high enough to provide the required phase resolution of the received signal for the position accuracy needed. |

*See Appendix A for detailed analysis.

# 7. CONCLUSIONS AND RECOMMENDATIONS

## 7.1 Comments and Recommendations Concerning the Sensor Data Base

The computer data file and the operating search programs* have been supplied to the Coast Guard. A continuing program of data base updating is recommended to insure that new sensor information is made available for analysis. The morphological analyses explored in the course of this project, have, of necessity, had to be quite general. The technique is even more appropriate to specific sensor requirements, because the descriptor fields are smaller and the process of deriving a residual taxonomy can be eliminated.

In the course of the morphological analysis, descriptor changes were found to be needed for some of the sensors. A detailed review of the data base is thus recommended to insure that any subsequent analyses will pick up a minimum of non-relevant matches.

A major advantage of a taxonometric data catalog is that it is not as sensitive to specific word selection as is a strictly key word type of catalog. The field descriptors of the taxonomy are chosen to be generally descriptive concepts rather than specific key words. Thus when a data entry is cataloged, it is only necessary that the correct general descriptors be chosen. This is a much easier task than picking the right set of key words.

Specific sensor information is recovered from the taxonometrically organized data base by searching with a set of descriptors in mutually independent fields rather than by

*Instructions for operating the programs are included in Appendix B.

searching with the correct key-word. However, in setting up the taxonomy, cataloging the data, and then searching for specific information, it is important to eliminate or minimize the problem of circularity. This may result if the same person performs all three tasks. He is able to find the correct information because he knows how he put it in and what to ask for, but someone else may not have the same set of concepts about the desired infromation and hence not get the proper output from his search. Ideally, the taxonomy should be organized by a panel of experts and the data should be cataloged by a panel of experts so that the descriptor fields are known to have the same general meaning to most of the user population.

## 7.2 Summary of Sensor Development Recommendations

Sensor systems which seem particularly interesting for specific Coast Guard applications, as determined by the morphological analysis procedure, are summarized below under the operational activity heading. Appropriate further action on any of these sensor systems and system concepts is to be decided by the Coast Guard after consideration of program priorities and technical development costs.

### *Search and Rescue*

The growth in satellite-communication technology which will occur when space-shuttle operations commence should be utilized to provide world-wide coverage of emergency beacon transmission. Electronic miniaturization procedures will permit emergency radio beacons to be carried as standard life-jacket equipment. Pop-up emergency beacons with deployable floatation should be developed for submersible and diver use.

The improved resolution available in search radars should be utilized by providing better radar visibility for liferafts and distressed personnel in the water. Deployable aluminized radar reflectors, in fluorescent colors, inflated with helium or hydrogen, may be one way of improving rescue probability.

Increased use should be made of electronic optical aids such as low-light level and IR imaging devices. Specialized sensors for the color spectra of dyes would enable more effective use of dye patches as search aids.

The technology involved in rescuing survivors on the surface by using a submersible should be investigated. Development of a rescue capsule which could be brought down to an airlock-equipped submersible would minimize the hazards of rescue operations in high sea states.

*Oil Spill Detection and Classification*

The imaging capabilities of satellites in the optical and microwave bands useful for oil-spill detection are being improved, however the data-rates required for resolution of small spills make satellite detection impractical unless on-board processing is used. If ground-based processing is used, a near real-time processing speed is needed to provide timely input to classification and clean-up teams. Present processing of satellite and aircraft imagery requires days to weeks.

Synthetic aperture radar systems, presently being developed for other missions can be adapted to oil-spill detection. The proper choice of radar wavelength and optical wavelengths for airborne detectors should be investigated.

Classification of oil spills generally is carried out by special missions to the site after a detection by a routine surveillance mission has occurred. If a means of classifying a spill were provided to the surveillance aircraft, the second, special mission would be avoided. A technique for collecting samples by a patrol aircraft could be developed. Alternatively, an integrated multisensor system could be operated from a patrol helicopter or airship. An airship would have the advantage of long range and high carrying capacity for on-board analysis equipment.

*Offshore Law Enforcement*

Satellite imagery having sufficient resolution to detect and track all offshore shipping would require data rates which are impractically high for present telemetry and processing equipment. If ships were provided with an onboard ID beacon, this would greatly reduce the information processing required to track their location. However, a cooperative target is thus required, which is usually not the case with illegal ship activities. Thus, detection and tracking of potential illegal ship movements will continue to be done by land and aircraft radar systems.

Synthetic aperture radar imagery should be developed further for high altitude aircraft surveillance of important ocean areas for surface ship activity. Submersible activity surveillance is not as easily performed, but special processing of magnetometer data may be devised to provide imagery of a moving anomaly produced by a submersible, against the stationary terrain-related anomaly background. The effective range of present magnetometer systems is limited so that aircraft surveillance of an extensive area is not feasible. Magnetic cable "barriers" to detect submersibles and surface vessels may be more practical at harbor entrances or shorefronts where illegal landings may occur.

Passive underwater detection of surface vessel or submersible activity is feasible at operationally useful ranges if the target has a unique acoustic signature which is distinguishable from the ambient background caused by other shipping or by wave action.

*Ice Operations*

Sensor technology relating to ice measurement and mapping and to helicopter-aided icebreaker operations was analyzed. Local underwater acoustic or optical sensors could monitor ice conditions in commercially important remote narrows and other navigable passages. Data relay via satellite would provide timely warning of impending passage closure. The imaging radar which will be available on SEASAT-A will provide data on general ice coverage and ice movement in more open water. Available techniques using radar, IR and electromagnetic pulses for remote measurement of ice thickness and composition need further development to improve accuracy and resolution.

Since it is generally not feasible to mount a conventional sonar on an icebreaker, some other means of providing underwater sensing of ice conditions ahead of the ship is needed. Improvement of remote ice-sounding sensors would make helicopters more effective for this purpose. The development of a remotely-controlled vehicle should be considered for either surface or underwater operation. The vehicle would carry ice measurement sensors and navigation equipment. Sensors on the vehicle would transmit both data and position information back to the ship by direct cable or by acoustic telemetry. This vehicle could thus be used either alone or in conjunction with the helicopter to map the ice field ahead of the ship.

The helicopter itself might be replaced with a tethered balloon or other non-manned air platform to carry a range of instruments.

*Port Safety and Security*

The analysis was directed primarily at the aspects of port security relating to water based sabotage and terrorist activity.

Detection of swimmers is a difficult sensing task. For underwater swimmers, high frequency doppler-shift sensing sonar is required to distinguish moving targets from the reverberation and stationary target background. Bistatic, shadow-detecting, sonars should be developed for this task. For surface swimmers at night, low light level and infra-red scanning sensors (FLIR) are applicable at short ranges. For longer ranges, high-resolution radar has been found to work under low sea-state conditions. For detecting bottom swimmers, an upward-looking barrier type of sonar system similar to acoustic fish counters can be developed. These could be placed across pier heads and other areas to be protected.

Small submersibles may be used for clandestine activities. Sufficient electrically conductive material is usually contained in the vehicle to permit detection by pulsed-magnetic field sensors. This system can consist of long loops of electrical cable oriented to provide a barrier system. Alternatively, fixed or steerable bottom scanning sonars may be used.

*Underwater Aids to Navigation*

The analysis in this activity was directed at areas and circumstances where underwater navaids would provide unique capabilities not available from standard surface equipment.

Polar commercial channels where ice cover makes buoy and day-mark installation difficult could benefit from installation of an underwater acoustic beacon system.. This system could be used by a relatively simple direction finding receiver installation, either temporary or permanent, on the user vessels. In the advent of commercial cargo submersibles, the underwater acoustic beacons would be the most appropriate navaid.

Underwater acoustic markers – either transponders, or passive reflectors – would provide a readily observable reference marker for buoy anchor location. When buoys were moved off stations by ice or storms the exact position could be refound by scanning sonar or by a pointer-locator system, once the general area had been located by conventional surface navigation.

## APPENDIX A — RESIDUAL PROGRAM OUTPUT AND MORPHOLOGICAL ANALYSIS RESULTS

Contents — Sensor System Residual Taxonomy Analysis



This appendix contains the output of the RESIDUAL program which was run for each of the above taxonomies. This program performs a search of the sensor data base for each morphological combination permitted by the residual sensor descriptors. The sensors which match each descriptor combination are identified by their key number which is printed to the right of the line specifying the morphology.

An analysis was made of each morphology and summarized on the data sheets accompanying the program output. The line numbers of the analysis corresponds to the line number of the morphological combination on the computer output. A complete explanation of the format is given in Figs. 6.1 and 6.2 of Section 6.

# FIG. A.1. RESIDUAL RESCUE MORPHOLOGY

SEARCH OVER THE FOLLOWING

| ---ENVIRONMENT DESCRIPTORS--- | ---OBJECT DESCRIPTORS--- |
|---|---|
| 6.1 AT SENSOR<br>.AIR<br>.SURFACE<br>.UNDERWATER | 7.1 NATURE OF OBJECT SENSED<br>DISCRETE OBJECT<br>.ANIMATE(DISC.)<br>.SOLID(DISC.) |
| 6.2 AT OBJECT<br>.SURFACE<br>.BOTTOM | 7.3 OBJECT INFORMATION<br>INFORMATION TRANSFER<br>.COMMUNICATION<br>.SYSTEM CONTROL |
| 6.3 SENSOR PLATFORM<br>.MOBILE, CONTROLLED | SYNOPTIC INFO.<br>.IDENTIFY FEATURES |
| 6.4 SENSOR OBJECT PROXIMITY<br>.REMOTE | |

| | ENV. AT SENSOR | ENV. AT OBJECT | SENSOR PLATFORM | PROXIMITY | OBJECT SENSED | OBJECT INFO. | | |
|---|---|---|---|---|---|---|---|---|
| 1 | AIR | SURFACE | MOBILE, CONTROLLED | REMOTE | ANIMATE(DISC.) | COMMUNICATION | | |
| 2 | AIR | SURFACE | MOBILE, CONTROLLED | REMOTE | ANIMATE(DISC.) | SYSTEM CONTROL | | |
| 3 | AIR | SURFACE | MOBILE, CONTROLLED | REMOTE | ANIMATE(DISC.) | IDENTIFY FEATURES | 64 | 94 |
| 120 158 205 213 231 | | | | | | | | |
| 4 | AIR | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COMMUNICATION | 226 | |
| 5 | AIR | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SYSTEM CONTROL | 236 | |
| 6 | AIR | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | IDENTIFY FEATURES | 6 | 17 |
| 64 94 120 158 213 214 229 231 245 | | | | | | | | |
| 7 | AIR | BOTTOM | MOBILE, CONTROLLED | REMOTE | ANIMATE(DISC.) | COMMUNICATION | | |
| 8 | AIR | BOTTOM | MOBILE, CONTROLLED | REMOTE | ANIMATE(DISC.) | SYSTEM CONTROL | | |
| 9 | AIR | BOTTOM | MOBILE, CONTROLLED | REMOTE | ANIMATE(DISC.) | IDENTIFY FEATURES | | |
| 10 | AIR | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COMMUNICATION | | |
| 11 | AIR | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SYSTEM CONTROL | | |
| 12 | AIR | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | IDENTIFY FEATURES | | |
| 13 | SURFACE | SURFACE | MOBILE, CONTROLLED | REMOTE | ANIMATE(DISC.) | COMMUNICATION | 102 | |
| 14 | SURFACE | SURFACE | MOBILE, CONTROLLED | REMOTE | ANIMATE(DISC.) | SYSTEM CONTROL | | |
| 15 | SURFACE | SURFACE | MOBILE, CONTROLLED | REMOTE | ANIMATE(DISC.) | IDENTIFY FEATURES | 158 | |
| 16 | SURFACE | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COMMUNICATION | | |
| 17 | SURFACE | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SYSTEM CONTROL | | |
| 18 | SURFACE | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | IDENTIFY FEATURES | 158 | |
| 19 | SURFACE | BOTTOM | MOBILE, CONTROLLED | REMOTE | ANIMATE(DISC.) | COMMUNICATION | | |
| 20 | SURFACE | BOTTOM | MOBILE, CONTROLLED | REMOTE | ANIMATE(DISC.) | SYSTEM CONTROL | | |
| 21 | SURFACE | BOTTOM | MOBILE, CONTROLLED | REMOTE | ANIMATE(DISC.) | IDENTIFY FEATURES | | |
| 22 | SURFACE | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COMMUNICATION | | |
| 23 | SURFACE | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SYSTEM CONTROL | | |
| 24 | SURFACE | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | IDENTIFY FEATURES | | |
| 25 | UNDERWATER | SURFACE | MOBILE, CONTROLLED | REMOTE | ANIMATE(DISC.) | COMMUNICATION | 108 | |
| 26 | UNDERWATER | SURFACE | MOBILE, CONTROLLED | REMOTE | ANIMATE(DISC.) | SYSTEM CONTROL | | |
| 27 | UNDERWATER | SURFACE | MOBILE, CONTROLLED | REMOTE | ANIMATE(DISC.) | IDENTIFY FEATURES | (94) | |
| 28 | UNDERWATER | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COMMUNICATION | 78 | 84 |
| 108 | | | | | | | | |
| 29 | UNDERWATER | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SYSTEM CONTROL | | |
| 30 | UNDERWATER | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | IDENTIFY FEATURES | (94) | |
| 31 | UNDERWATER | BOTTOM | MOBILE, CONTROLLED | REMOTE | ANIMATE(DISC.) | COMMUNICATION | | |
| 32 | UNDERWATER | BOTTOM | MOBILE, CONTROLLED | REMOTE | ANIMATE(DISC.) | SYSTEM CONTROL | | |
| 33 | UNDERWATER | BOTTOM | MOBILE, CONTROLLED | REMOTE | ANIMATE(DISC.) | IDENTIFY FEATURES | 114 | 17 |
| 4 | | | | | | | | |
| 34 | UNDERWATER | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COMMUNICATION | | |
| 35 | UNDERWATER | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SYSTEM CONTROL | 143 | 19 |
| 3 175A 277 | | | | | | | | |
| 36 | UNDERWATER | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | IDENTIFY FEATURES | 51 | 73 |
| 114 141 151 152 154 164 171 174 176 | | | | | | | | |

FIG. A.2. MORPHOLOGICAL ANALYSIS — RESCUE

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 1 | Communication from aircraft or airship with swimmer | Aircraft mounted loudspeakers (1-way) or radio in drop-pack (2-way) | 0** | | | ✓ | | | |
| 2 | Homing beacon on swimmer to aid aircraft in locating | Emergency rescue radio transmitter for swimmer use | 0 | | | | ✓ | | ✓ |
| 3 | Location and identification of distressed swimmer from aircraft | Visual, FLIR and high res. radar, dye patch, deployable radar reflector | 3 | 4 | | ✓ | ✓ | | |
| 4 | Communication between vessel in distress and aircraft | VHF radio, or other emergency radio equipment | 1 | | | ✓ | | | |
| 5 | Homing transmitter on distressed vessel (lifeboat) for aircraft aid | VHF radio, as above | 1 | | | ✓ | | | |
| 6 | Location and identification of distressed vessel (lifeboat) | FLIR, high res. radar, visual sensors — dye patch, radar ref | 5 | 6 | | ✓ | | | |
| 7 | Communication from aircraft (airship) to distressed diver on bottom | Pop-up type of emergency transmitter hooked to diver comm. set | 0 | | | | ✓ | | |
| 8 | Homing transmitter from distressed diver for aircraft aid | As above, but only code transmitter for locating purposes | 0 | | | | ✓ | | ✓ |
| 9 | Location and identification of distressed diver on bottom by aircraft | As above for cooperative victim, emergency pinger on diver and aircraft launched directional sonobuoy for disabled victim | 0 | | | ✓ | ✓ | | |
| 10 | Communication from aircraft (airship) to distressed submissible | Pop-up emergency transmitter from submersible (see key number 234) | 1* | | | ✓ | ✓ | | ✓ |
| 11 | Homing beacon from distressed submersible for aircraft aid | Pop-up radio transmitter operating on RDF frequencies | 0 | | | | ✓ | | ✓ |
| 12 | Location and identification of distressed submersible by aircraft | Similar to line 9 above, also dipping sonar on aircraft | 0 | | | ✓ | ✓ | | ✓ |
| 13 | Communication from distressed swimmer to rescue vessel (surface) | Aural (shouting, emergency whistle) possibly augmented by directional microphone system, emergency radio for swimmer | 0 | 1 | | ✓ | ✓ | | ✓ |
| 14 | Device to assist rescue to home on swimmer location | Directional microphone for acoustic signals, emergency radio light flare | 0 | | | | ✓ | | ✓ |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

R - RELEVANT SENSORS FOUND, C - CLOSE TECHNOLOGY, N.R. - TECH. NOT REL., E - EXISTING TECH, OK, D - SPECIFIC DEVOPMENT REQ, N - NEW TECH REQ

FIG. A.2. MORPHOLOGICAL ANALYSIS — RESCUE

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 15 | Location and identification of swimmer by rescue vessel | Visual and FLIR sensors, low light level TV, aural signals | 1 | | | ✓ | ✓ | | ✓ |
| 16 | Communication between distressed vessel (liferaft, etc.) and rescue vessel | Normal emergency radio channels and equipment | 1* | | | ✓ | | | |
| 17 | Homing assistance from distressed vessel | VHF radio and RDF (see key number 236) | 1* | | | ✓ | | | |
| 18 | Location and identification of distressed vessel by rescue craft | Visual, FLIR, low light-level TV, high resolution radar | 1 | | | ✓ | | | |
| 19 | Communication between distressed diver and rescue vessel | Pop-up radio transmitter hooked to diver comm. set. Diver comm. equipment on rescue vessel (see key numbers 2, 181, 198A, 198B, 239) | 5* | | | ✓ | ✓ | | ✓ |
| 20 | Homing device to assist surface vessel to locate diver, remotely controlled rescue device | Emergency pinger on diver and directional hydrophones on rescue vessel. Remote controlled rescue device sent down from surface (see key numbers 153, 277) | 2* | | | ✓ | ✓ | | ✓ |
| 21 | Location and identification of distressed diver by rescue vessel | High resolution sonar, remote controlled underwater TV, pingers (see key numbers 153, 164, 174, 277) | 4* | | | ✓ | | | |
| 22 | Communication between distressed submersible or underwater habitat and surface rescue vessel | Underwater telephone, coded pinger, pop-up radio equipment (see key numbers 181, 183, 234) | 3* | | | ✓ | ✓ | | ✓ |
| 23 | Homing of rescue vessel on location of distressed submersible | Emergency pinger and locator equipment, transponders (see key numbers 153, 277) | 2* | | | ✓ | | | |
| | Auto-controlled rescue device from surface to submersible | Acoustic telemetry, underwater TV, navigation sonars (key numbers 58, 83, 174) | 3* | | | ✓ | ✓ | | ✓ |
| 24 | Location and identification of distressed submersible from rescue vessel | Side-scan sonar, underwater TV, coded pingers (see line 21) | 4* | | | ✓ | | | |
| 25 | Communication from submersible to distressed swimmer | Modification of diver comm. equipment, acoustic or elect. field (key 102) | 1* | 1 | | | ✓ | | |
| 26 | Distressed swimmer locator device for submersible | Emergency pinger and directional hydrophones (key 153, 277) | 0 | 2* | | ✓ | ✓ | | ✓ |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

R - RELEVANT SENSORS FOUND, C - CLOSE TECHNOLOGY, N.R. - TECH. NOT REL., E - EXISTING TECH, OK, D - SPECIFIC DEVOPMENT REQ, N - NEW TECH REQ

FIG. A.2. MORPHOLOGICAL ANALYSIS — RESCUE

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 27 | Identification of distressed swimmer by submersible | As above, if swimmer is equipped, doppler sonar otherwise (key 116) | 1* | 2* | 1 | ✓ | ✓ | | ✓ |
| 28 | Communication from distressed surface vessel to rescue submersible | Underwater telephone, ELF EM radiation, coded pinger (key 153, 183) | 2 | 1 | | ✓ | ✓ | | ✓ |
| 29 | Locator device on distressed surface vessel to assist rescue submersible | Pinger, transponder with direction receiver on submersible (key 153, 277) | 2* | | | ✓ | | | |
| 30 | Identification of distressed surface vessel from submersible | As above, if vessel is equipped, otherwise doppler sonar (key 116) | 1* | | 1 | ✓ | ✓ | | ✓ |
| 31 | Communication from distressed diver to rescue submersible | Diver communication equipment (key numbers 2, 181, 198A, 198B, 239) | 5* | | | ✓ | | | |
| 32 | Locator device on distressed diver to aid rescue submersible | Emergency pinger and directional receiver on sub. (key 197, 198, 188, 189) | 4* | | | ✓ | | | |
| 33 | Identification of distressed diver by rescue submersible | High resolution sonar, underwater TV, direct visual means | 2 | | | ✓ | | | |
| 34 | Communication from distressed sub or habitat on bottom with rescue submersible | Underwater telephone, coded pinger, ELF EM radiation (key numbers 78, 108, 183) | 3* | | | ✓ | ✓ | | ✓ |
| 35 | Locator device on distressed sub to aid rescue submersible | Emergency pingers and directional receiver on rescue sub | 2 | 2 | | ✓ | | | |
| 36 | Identification of distressed sub by rescue submersible | High resolution sonar, underwater TV, direct visual means | 9 | 2 | | ✓ | | | |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

R - RELEVANT SENSORS FOUND, C - CLOSE TECHNOLOGY, N.R. - TECH. NOT REL., E - EXISTING TECH, OK, D - SPECIFIC DEVOPMENT REQ, N - NEW TECH REQ

## FIG. A.3. RESIDUAL OIL SPILL DETECTION

FY FEATURES 95 118
SEARCH OVER THE FOLLOWING

---ENVIRONMENT DESCRIPTORS---
6.1 AT SENSOR
.SPACE
.AIR
6.2 AT OBJECT
.SURFACE
6.3 SENSOR PLATFORM
.MOBILE, CONTROLLED
6.4 SENSOR OBJECT PROXIMITY
.REMOTE

---OBJECT DESCRIPTORS---
7.1 NATURE OF OBJECT SENSED
DISCRETE OBJECT
.LIQUID(DISC.)
.FILM
7.2 OBJECT-STIMULUS INTERACTION
ACTIVE OBJECT
.STIMULATED EMISS.
.SPONTANEOUS EMISS.
PASSIVE OBJECT
.REFLECTION
.SCATTERING
.ABSORPTION
7.3 OBJECT INFORMATION
SYNOPTIC INFO.
.DETECT PRESENCE
.IDENTIFY FEATURES
GEOMETRIC INFO.
.2-D SURFACE IMAGE

| | ENV. AT SENSOR | ENV. AT OBJECT | SENSOR PLATFORM | PROXIMITY | OBJECT SENSED | INTERACTION | OBJECT INFO. | |
|---|---|---|---|---|---|---|---|---|
| 1 | SPACE | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | STIMULATED EMISS. | DETECT PRESENCE | |
| 2 | SPACE | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | STIMULATED EMISS. | IDENTIFY FEATURES | |
| 3 | SPACE | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | STIMULATED EMISS. | 2-D SURFACE IMAGE | |
| 4 | SPACE | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | SPONTANEOUS EMISS. | DETECT PRESENCE | 132 133 160 (205) |
| 5 | SPACE | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | SPONTANEOUS EMISS. | IDENTIFY FEATURES | 33 148A 160 (205) |
| 6 | SPACE | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | SPONTANEOUS EMISS. | 2-D SURFACE IMAGE | 5 33 40 85 148A 150 160 (201) 148C |
| 7 | SPACE | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | REFLECTION | DETECT PRESENCE | 160 (205) (283) |
| 8 | SPACE | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | REFLECTION | IDENTIFY FEATURES | (41) 43 160 (205) (283) |
| 9 | SPACE | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | REFLECTION | 2-D SURFACE IMAGE | 41 43 160 (283) |
| 10 | SPACE | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | SCATTERING | DETECT PRESENCE | 160 (205) (283) |
| 11 | SPACE | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | SCATTERING | IDENTIFY FEATURES | 160 (205) (283) |
| 12 | SPACE | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | SCATTERING | 2-D SURFACE IMAGE | (123) (150) 160 (283) |

FIG. A.3. *(Cont.)*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 13 SPACE PRESENCE | | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | ABSORPTION | DETECT |
| 14 SPACE FY FEATURES | | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | ABSORPTION | IDENTI |
| 15 SPACE RFACE IMAGE | | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | ABSORPTION | 2-D SU |
| 16 SPACE PRESENCE | (95) | SURFACE | MOBILE, CONTROLLED | REMOTE | FILM | STIMULATED EMISS. | DETECT |
| 17 SPACE | | SURFACE | MOBILE, CONTROLLED | REMOTE | FILM | STIMULATED EMISS. | IDENTI |
| 18 SPACE RFACE IMAGE | | SURFACE | MOBILE, CONTROLLED | REMOTE | FILM | STIMULATED EMISS. | 2-D SU |
| 19 SPACE PRESENCE | 132 133 160 (205) | SURFACE | MOBILE, CONTROLLED | REMOTE | FILM | SPONTANEOUS EMISS. | DETECT |
| 20 SPACE FY FEATURES | 33 160 (205) | SURFACE | MOBILE, CONTROLLED | REMOTE | FILM | SPONTANEOUS EMISS. | IDENTI |
| 21 SPACE RFACE IMAGE | 33 85 (150) 160 148C | SURFACE | MOBILE, CONTROLLED | REMOTE | FILM | SPONTANEOUS EMISS. | 2-D SU |
| 22 SPACE PRESENCE | (95) 118 160 (205) (283) | SURFACE | MOBILE, CONTROLLED | REMOTE | FILM | REFLECTION | DETECT |
| 23 SPACE FY FEATURES | 118 160 (205) (283) | SURFACE | MOBILE, CONTROLLED | REMOTE | FILM | REFLECTION | IDENTI |
| 24 SPACE RFACE IMAGE | 118 160 (283) | SURFACE | MOBILE, CONTROLLED | REMOTE | FILM | REFLECTION | 2-D SU |
| 25 SPACE PRESENCE | (95) 160 (205) (283) | SURFACE | MOBILE, CONTROLLED | REMOTE | FILM | SCATTERING | DETECT |
| 26 SPACE FY FEATURES | 160 (205) (283) | SURFACE | MOBILE, CONTROLLED | REMOTE | FILM | SCATTERING | IDENTI |
| 27 SPACE RFACE IMAGE | (150) 160 (283) | SURFACE | MOBILE, CONTROLLED | REMOTE | FILM | SCATTERING | 2-D SU |
| 28 SPACE PRESENCE | 118 | SURFACE | MOBILE, CONTROLLED | REMOTE | FILM | ABSORPTION | DETECT |
| 29 SPACE FY FEATURES | 118 | SURFACE | MOBILE, CONTROLLED | REMOTE | FILM | ABSORPTION | IDENTI |
| 30 SPACE RFACE IMAGE | 118 | SURFACE | MOBILE, CONTROLLED | REMOTE | FILM | ABSORPTION | 2-D SU |
| 31 AIR PRESENCE | 230 282 | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | STIMULATED EMISS. | DETECT |
| 32 AIR FY FEATURES | (94) | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | STIMULATED EMISS. | IDENTI |
| 33 AIR RFACE IMAGE | (94) | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | STIMULATED EMISS. | 2-D SU |
| 34 AIR PRESENCE | 64 90A 90B 90C 132 133 158 (205) 213 | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | SPONTANEOUS EMISS. | DETECT |
| 35 AIR FY FEATURES | 6 17 64 90A 90B 90C 158 (205) 213 | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | SPONTANEOUS EMISS. | IDENTI |
| 36 AIR RFACE IMAGE | 6 17 64 85 90A 90B 90C 158 (202) 213 | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | SPONTANEOUS EMISS. | 2-D SU |
| 37 AIR PRESENCE | 900 (205) 214 (229) 230 | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | REFLECTION | DETECT |
| 38 AIR FY FEATURES | 900 94 180 (205) 214 (229) | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | REFLECTION | IDENTI |
| 39 AIR RFACE IMAGE | 900 94 214 (229) | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | REFLECTION | 2-D SU |
| 40 AIR PRESENCE | 900 (205) | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | SCATTERING | DETECT |
| 41 AIR FY FEATURES | 900 180 (205) | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | SCATTERING | IDENTI |
| 42 AIR RFACE IMAGE | 900 | SURFACE | MOBILE, CONTROLLED | REMOTE | LIQUID(DISC.) | SCATTERING | 2-D SU |

FIG. A.3. *(Cont.)*

| | | | | | | |
|---|---|---|---|---|---|---|
| 43 AIR PRESENCE | | SURFACE | MOBILE, CONTROLLED REMOTE | LIQUID(DISC.) | ABSORPTION | DETECT |
| 44 AIR FY FEATURES | | SURFACE | MOBILE, CONTROLLED REMOTE | LIQUID(DISC.) | ABSORPTION | IDENTI |
| 45 AIR RFACE IMAGE | | SURFACE | MOBILE, CONTROLLED REMOTE | LIQUID(DISC.) | ABSORPTION | 2-D SU |
| 46 AIR PRESENCE | (95) 211 228 | SURFACE | MOBILE, CONTROLLED REMOTE | FILM | STIMULATED EMISS. | DETECT |
| 47 AIR FY FEATURES | (94) | SURFACE | MOBILE, CONTROLLED REMOTE | FILM | STIMULATED EMISS. | IDENTI |
| 48 AIR RFACE IMAGE | (94) | SURFACE | MOBILE, CONTROLLED REMOTE | FILM | STIMULATED EMISS. | 2-D SU |
| 49 AIR PRESENCE | 64 90A 90B 90C 132 133 (205) 213 | SURFACE | MOBILE, CONTROLLED REMOTE | FILM | SPONTANEOUS EMISS. | DETECT |
| 50 AIR FY FEATURES | 6 64 90A 90B 90C (205) 213 | SURFACE | MOBILE, CONTROLLED REMOTE | FILM | SPONTANEOUS EMISS. | IDENTI |
| 51 AIR RFACE IMAGE | 6 64 85 90A 90B 90C 105 213 | SURFACE | MOBILE, CONTROLLED REMOTE | FILM | SPONTANEOUS EMISS. | 2-D SU |
| 52 AIR PRESENCE | 900 (95) 111 (205) | SURFACE | MOBILE, CONTROLLED REMOTE | FILM | REFLECTION | DETECT |
| 53 AIR FY FEATURES | 900 94 111 180 (205) | SURFACE | MOBILE, CONTROLLED REMOTE | FILM | REFLECTION | IDENTI |
| 54 AIR RFACE IMAGE | 900 94 111 | SURFACE | MOBILE, CONTROLLED REMOTE | FILM | REFLECTION | 2-D SU |
| 55 AIR PRESENCE | 900 (95) (205) | SURFACE | MOBILE, CONTROLLED REMOTE | FILM | SCATTERING | DETECT |
| 56 AIR FY FEATURES | 900 180 205 | SURFACE | MOBILE, CONTROLLED REMOTE | FILM | SCATTERING | IDENTI |
| 57 AIR RFACE IMAGE | 900 | SURFACE | MOBILE, CONTROLLED REMOTE | FILM | SCATTERING | 2-D SU |
| 58 AIR PRESENCE | | SURFACE | MOBILE, CONTROLLED REMOTE | FILM | ABSORPTION | DETECT |
| 59 AIR FY FEATURES | | SURFACE | MOBILE, CONTROLLED REMOTE | FILM | ABSORPTION | IDENTI |
| 60 AIR RFACE IMAGE | | SURFACE | MOBILE, CONTROLLED REMOTE | FILM | ABSORPTION | 2-D SU |

FIG. A.4. MORPHOLOGICAL ANALYSIS — OIL SPILL DETECTION

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS R | C | NR | INDICATED TECH E | D | N | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Detection by stimulated emission from space | Very difficult. Not recommended since other, easier techniques are available. | 0 | | | | | ✓ | |
| 2 | Identify features by stimulated emission from space | | 0 | | | | | ✓ | |
| 3 | 2-D imaging by stimulated emission from space | | 0 | | | | | ✓ | |
| 4 | Detection from space by self-emission | Needed for night detection. Both infrared and microwave techniques are represented. Automated data reduction techniques need improvement to obtain faster responses. | 1 | 2 | 1 | ✓ | ✓ | | ✓ |
| 5 | Identify features from space by self-emission | | 3 | - | 1 | ✓ | ✓ | | ✓ |
| 6 | 2-D map from space by self-emission | | 5 | 2 | 2 | ✓ | ✓ | | ✓ |
| 7 | Detection from space by reflection | Imaging systems using visible or IR with sun as source, and microwave with active transmitter on satellite as source. Faster data reduction needed here also. | 1 | | 2 | ✓ | ✓ | | ✓ |
| 8 | Identify features from space by reflection | | 2 | | 3 | ✓ | ✓ | | ✓ |
| 9 | 2-D map | | 2 | | 2 | ✓ | ✓ | | ✓ |
| 10 | Detection from space by scattering | Comments under lines 7-9 apply | 1 | | 2 | ✓ | ✓ | | ✓ |
| 11 | Identify features from space by scattering | | 1 | | 2 | ✓ | ✓ | | ✓ |
| 12 | 2-D map | | 1 | | 3 | ✓ | ✓ | | ✓ |
| 13 | Detection from space by absorption | Very difficult, though probably slightly less so than by stimulated emission. Not recommended since other, easier techniques are available. | 0 | | | | | ✓ | |
| 14 | Identify features from space by absorption | | 0 | | | | | ✓ | |
| 15 | 2-D map | | 0 | | | | | ✓ | |
| 16 | Same as 1-3 except for film rather than liquid | Same as 1-3 except for film rather than liquid | 0 | | 1 | | | ✓ | |
| 17 | " | " | 0 | | | | | ✓ | |
| 18 | " | " | 0 | | | | | ✓ | |
| 19 | Same as 4-6 except for film rather than liquid | Same as 4-6 except for film rather than liquid | 1 | 2 | 1 | ✓ | ✓ | | ✓ |
| 20 | " | " | 2 | | 1 | ✓ | ✓ | | ✓ |
| 21 | " | " | 3 | 1 | 1 | ✓ | ✓ | | ✓ |
| 22 | Same as 7-12 except for film rather than liquid | Same as 7-12 except for film rather than liquid | 2 | | 3 | ✓ | ✓ | | ✓ |
| 23 | " | " | 2 | | 2 | ✓ | ✓ | | ✓ |
| 24 | " | " | 2 | | 1 | ✓ | ✓ | | ✓ |
| 25 | " | " | 1 | | 3 | ✓ | ✓ | | ✓ |
| 26 | " | " | 1 | | 2 | ✓ | ✓ | | ✓ |
| 27 | " | " | 1 | | 2 | ✓ | ✓ | | ✓ |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

R - RELEVANT SENSORS FOUND, C - CLOSE TECHNOLOGY, N.R. - TECH. NOT REL., E - EXISTING TECH, OK, D - SPECIFIC DEVELOPMENT REQ, N - NEW TECH REQ

FIG. A.4. MORPHOLOGICAL ANALYSIS — OIL SPILL DETECTION

| REF LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 28 | Same as 13-15 except for film rather than liquid | Same as 13-15 except for film rather than liquid | 1* | | | | | ✓ | |
| 29 | " | " | 1* | | | | | ✓ | |
| 30 | " | " | 1* | | | | | ✓ | |
| 31 | Detection by stimulated emission, from aircraft | Difficult technique to implement. Spill detection probably better done by other techniques | 1 | 1 | | ✓ | ✓ | | |
| 32 | Identify features by stimulated emission, from aircraft | | 0 | | 1 | | ✓ | | |
| 33 | 2-D Map by stimulated emission, from aircraft | | 0 | | 1 | | ✓ | | |
| 34 | Detection from aircraft by self emission | IR systems. Probably need development to apply to specific problem | 5 | 3 | 1 | ✓ | ✓ | | ✓ |
| 35 | Identify features from aircraft by self emission | | 5 | 2 | 1 | ✓ | ✓ | | ✓ |
| 36 | 2-D Map from aircraft by self emission | | 7 | 2 | 1 | ✓ | ✓ | | ✓ |
| 37 | Detection from aircraft by reflection | Imagery system using sun as source for visible and IR approaches and using airborne transmitter for microwave approaches. Needs improved data reduction and interpertation schemes to obtain information more rapidly. | 3 | | 2 | ✓ | ✓ | | ✓ |
| 38 | Identify features from aircraft by reflection | | 4 | | 2 | ✓ | ✓ | | ✓ |
| 39 | 2-D Map from aircraft by reflection | | 3 | | 1 | ✓ | ✓ | | ✓ |
| 40 | Detection from aircraft by scattering | Comments under lines 37-39 apply | 1 | | 1 | ✓ | ✓ | | ✓ |
| 41 | Identify features from aircraft by scattering | " | 2 | | 1 | ✓ | ✓ | | ✓ |
| 42 | 2-D Map from aircraft by scattering | " | 1 | | | ✓ | ✓ | | ✓ |
| 43 | Detection from aircraft by absorption | Probably impractical. Implies cooperative underwater source directly under spill site. | 0 | | | | | ✓ | |
| 44 | Identify features from aircraft by absorption | | 0 | | | | | ✓ | |
| 45 | 2-D Map from aircraft by absorption | | 0 | | | | | ✓ | |
| 46 | Same as 31-33 except for film rather than liquid | Same as 31-33 except for film rather than liquid | 2 | | | ✓ | ✓ | | |
| 47 | " | " | 0 | | | | ✓ | | |
| 48 | " | " | 0 | | | | ✓ | | |
| 49 | Same as 34-36 except for film rather than liquid | Same as 34-36 except for film rather than liquid | 5 | 2 | 1 | ✓ | ✓ | | ✓ |
| 50 | " | " | 6 | | 1 | ✓ | ✓ | | ✓ |
| 51 | " | " | 8 | | | ✓ | ✓ | | ✓ |
| 52 | Same as 37-42 except for film rather than liquid | Same as 37-42 except for film rather than liquid | 2 | | 2 | ✓ | ✓ | | ✓ |
| 53 | " | " | 4 | | 1 | ✓ | ✓ | | ✓ |
| 54 | " | " | 3 | | | ✓ | ✓ | | ✓ |
| 55 | " | " | 1 | | 2 | ✓ | ✓ | | ✓ |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

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FIG. A.4. MORPHOLOGICAL ANALYSIS — OIL SPILL DETECTION

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 56 | Same as 37-42 except for film rather than liquid | Same as 37-42 except for film rather than liquid | 2 | | 1 | ✓ | ✓ | | ✓ |
| 57 | " | " | 1 | | | ✓ | ✓ | | ✓ |
| 58 | Same as 43-45 except for film rather than liquid | Same as 43-45 except for film rather than liquid | 0 | | | | | ✓ | |
| 59 | " | " | 0 | | | | | ✓ | |
| 60 | " | " | 0 | | | | | ✓ | |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

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# FIG. A.5. RESIDUAL MORPHOLOGY — OIL SPILL CLASSIFICATION

SEARCH OVER THE FOLLOWING
RESIDUAL MORPHOLOGY-OIL SPILL CLASSIFICATION. 1/17/78. BASIC P

---ENVIRONMENT DESCRIPTORS---
6.1 AT SENSOR
  .AIR
  .SURFACE
  .UNDERWATER
6.2 AT OBJECT
  .SURFACE
  .UNDERWATER
  .BOTTOM

---OBJECT DESCRIPTORS---
7.2 OBJECT-STIMULUS INTERACTION
 ACTIVE OBJECT
  .STIMULATED EMISS.
  .SPONTANEOUS EMISS.
 PASSIVE OBJECT
  .REFLECTION
  .REFRACTION
  .SCATTERING
  .ABSORPTION
7.3 OBJECT INFORMATION
 SYNOPTIC INFO.
  .MEASURE PROPERTIES

| | ENV. AT SENSOR | ENV. AT OBJECT | INTERACTION | OBJECT INFO. | |
|---|---|---|---|---|---|
| 1 | AIR | SURFACE | STIMULATED EMISS. | MEASURE PROPERTIES | 4 99 (100) 107 (193) (211) 230 282 284 28 |
| 5 | 286 | | | | |
| 2 | AIR | SURFACE | SPONTANEOUS EMISS. | MEASURE PROPERTIES | 16 85 105 132 133 (149) 196 (202) (205) (21 |
| 2) | (258) | | | | |
| 3 | AIR | SURFACE | REFLECTION | MEASURE PROPERTIES | (91) (92) 159 180 (192) (195) (205) 218 230 |
| 4 | AIR | SURFACE | REFRACTION | MEASURE PROPERTIES | |
| 5 | AIR | SURFACE | SCATTERING | MEASURE PROPERTIES | 18 81 (92) (100) 159 180 (205) |
| 6 | AIR | SURFACE | ABSORPTION | MEASURE PROPERTIES | |
| 7 | AIR | UNDERWATER | STIMULATED EMISS. | MEASURE PROPERTIES | 99 (100) 230 284 285 286 |
| 8 | AIR | UNDERWATER | SPONTANEOUS EMISS. | MEASURE PROPERTIES | 132 133 (149) (212) (215) (244) |
| 9 | AIR | UNDERWATER | REFLECTION | MEASURE PROPERTIES | 230 |
| 10 | AIR | UNDERWATER | REFRACTION | MEASURE PROPERTIES | |
| 11 | AIR | UNDERWATER | SCATTERING | MEASURE PROPERTIES | 100 |
| 12 | AIR | UNDERWATER | ABSORPTION | MEASURE PROPERTIES | |
| 13 | AIR | BOTTOM | STIMULATED EMISS. | MEASURE PROPERTIES | 230 284 285 286 |
| 14 | AIR | BOTTOM | SPONTANEOUS EMISS. | MEASURE PROPERTIES | 132 133 (149) (177) (212) (215) |
| 15 | AIR | BOTTOM | REFLECTION | MEASURE PROPERTIES | 230 |
| 16 | AIR | BOTTOM | REFRACTION | MEASURE PROPERTIES | |
| 17 | AIR | BOTTOM | SCATTERING | MEASURE PROPERTIES | |
| 18 | AIR | BOTTOM | ABSORPTION | MEASURE PROPERTIES | |
| 19 | SURFACE | SURFACE | STIMULATED EMISS. | MEASURE PROPERTIES | 200 204 206 217 |
| 20 | SURFACE | SURFACE | SPONTANEOUS EMISS. | MEASURE PROPERTIES | (54) 132 133 (149) (157) (179) (212) (221) 226 |
| 21 | SURFACE | SURFACE | REFLECTION | MEASURE PROPERTIES | 93 |
| 22 | SURFACE | SURFACE | REFRACTION | MEASURE PROPERTIES | |
| 23 | SURFACE | SURFACE | SCATTERING | MEASURE PROPERTIES | 93 |
| 24 | SURFACE | SURFACE | ABSORPTION | MEASURE PROPERTIES | 135 204 227 287 289 |
| 25 | SURFACE | UNDERWATER | STIMULATED EMISS. | MEASURE PROPERTIES | 204 206 246 |
| 26 | SURFACE | UNDERWATER | SPONTANEOUS EMISS. | MEASURE PROPERTIES | 132 133 (149) (157) (212) 226 (243) |
| 27 | SURFACE | UNDERWATER | REFLECTION | MEASURE PROPERTIES | |
| 28 | SURFACE | UNDERWATER | REFRACTION | MEASURE PROPERTIES | |

FIG. A.5. *(Cont.)*

| | | | | | |
|---|---|---|---|---|---|
| 29 | SURFACE | UNDERWATER | SCATTERING | MEASURE PROPERTIES | |
| 30 | SURFACE | UNDERWATER | ABSORPTION | MEASURE PROPERTIES | 204 207 209 |
| 31 | SURFACE | BOTTOM | STIMULATED EMISS. | MEASURE PROPERTIES | |
| 32 | SURFACE | BOTTOM | SPONTANEOUS EMISS. | MEASURE PROPERTIES | (132) (133) (149) (177) (212) |
| 33 | SURFACE | BOTTOM | REFLECTION | MEASURE PROPERTIES | |
| 34 | SURFACE | BOTTOM | REFRACTION | MEASURE PROPERTIES | |
| 35 | SURFACE | BOTTOM | SCATTERING | MEASURE PROPERTIES | |
| 36 | SURFACE | BOTTOM | ABSORPTION | MEASURE PROPERTIES | |
| 37 | UNDERWATER | SURFACE | STIMULATED EMISS. | MEASURE PROPERTIES | 206 |
| 38 | UNDERWATER | SURFACE | SPONTANEOUS EMISS. | MEASURE PROPERTIES | 132 133 (149)-(157) (212) 226 |
| 39 | UNDERWATER | SURFACE | REFLECTION | MEASURE PROPERTIES | |
| 40 | UNDERWATER | SURFACE | REFRACTION | MEASURE PROPERTIES | |
| 41 | UNDERWATER | SURFACE | SCATTERING | MEASURE PROPERTIES | |
| 42 | UNDERWATER | SURFACE | ABSORPTION | MEASURE PROPERTIES | |
| 43 | UNDERWATER | UNDERWATER | STIMULATED EMISS. | MEASURE PROPERTIES | 55 59 (168) (169) 206 246 |
| 44 | UNDERWATER | UNDERWATER | SPONTANEOUS EMISS. | MEASURE PROPERTIES | (10) (32) (46) (48C) (62) (66) 69 (74) (96) (98) (115) (131) 132 133 (136) (144) (149) (157) (161D) 163A (172) (198A) (198B) (208) (212) (215) (224) 226 (235) (242) (243) (244) (254) (256) (163C) |
| 45 | UNDERWATER | UNDERWATER | REFLECTION | MEASURE PROPERTIES | (38) (127) (199) |
| 46 | UNDERWATER | UNDERWATER | REFRACTION | MEASURE PROPERTIES | (98) |
| 47 | UNDERWATER | UNDERWATER | SCATTERING | MEASURE PROPERTIES | 50 59 68 (70) (71) (72) (79) 161B (199) 222 |
| 48 | UNDERWATER | UNDERWATER | ABSORPTION | MEASURE PROPERTIES | (21) 30 50 68 (70) (71) (72) 77 (79) 161B 222 |
| 49 | UNDERWATER | BOTTOM | STIMULATED EMISS. | MEASURE PROPERTIES | 47 |
| 50 | UNDERWATER | BOTTOM | SPONTANEOUS EMISS. | MEASURE PROPERTIES | (65) (106) (115) 132 133 (149) (177) (212) (215) |
| 51 | UNDERWATER | BOTTOM | REFLECTION | MEASURE PROPERTIES | (97) (253) |
| 52 | UNDERWATER | BOTTOM | REFRACTION | MEASURE PROPERTIES | 253 |
| 53 | UNDERWATER | BOTTOM | SCATTERING | MEASURE PROPERTIES | |
| 54 | UNDERWATER | BOTTOM | ABSORPTION | MEASURE PROPERTIES | |

FIG. A.6. MORPHOLOGICAL ANALYSIS — OIL SPILL CLASSIFICATION

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 1 | Surface object with airborne sensor via stimulated emission | Remote Raman Spectroscopy probably not worth pursuing. Laser fluorescence may be a good bet. X-ray fluorescence too hazardous. Multispectral scanner would complement laser fluorescence. | 6 | 2 | 3 | | ✓ | | ✓ |
| 2 | Surface object with airborne sensor via spontaneous emission | Optical and microwave radiometry. Latter needs basic research to validate. Former needs engineering development. | 2 | 4 | 5 | | ✓ | | ✓ |
| 3 | Surface object with airborne sensor via reflection | Laser backscatter and multispectral scanner using sum as source. | 2 | 2 | 5 | | ✓ | | ✓ |
| 4 | Surface object with airborne sensor via refraction | Implies underwater source and aircraft receiver, both at known locations — probably impractical. | 0 | | | | | ✓ | |
| 5 | Surface object with airborne sensor via scattering | Laser techniques. Oil slick characterized by absence of spray. | 3 | 1 | 3 | | ✓ | | |
| 6 | Surface object with airborne sensor via absorption | Not practical as a remote technique. | 0 | | | | | ✓ | |
| 7 | Underwater object with airborne sensor via stimulated emission | Multispectral scanner seems best. Remote Raman not practical (X-ray technique not applicable.) | 4 | 1 | 1 | | ✓ | | ✓ |
| 8 | " spontaneous emission | " | 0 | 2 | 4 | | | ✓ | |
| 9 | Underwater object with airborne sensor via reflection | Multispectral scanner (microwave won't penetrate). | 1 | | | | ✓ | | ✓ |
| 10 | Underwater object with airborne sensor via refraction | Impractical (see entry 4) | 0 | | | | | ✓ | |
| 11 | Underwater object with airborne sensor via scattering | Not practical | 0 | | | | | ✓ | |
| 12 | Underwater object with airborne sensor via absorption | Not practical as a remote technique | 0 | | | | | ✓ | |
| 13 | Bottom object with airborne sensor via stimulated emission | Multispectral scanner is possibility (X-ray data base search error.) | 3 | 1 | | | ✓ | | |
| 14 | Bottom object with airborne sensor via spontaneous emission | Probably not feasible. | 0 | 2 | 4 | | | ✓ | |
| 15 | Bottom object with airborne sensor via reflection | Multispectral scanner. | 1 | | | | ✓ | | ✓ |

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**DATA BASE ADDITION NEEDED

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FIG. A.6. MORPHOLOGICAL ANALYSIS — OIL SPILL CLASSIFICATION

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 16 | Bottom object with airborne sensor via refraction | Impractical (see entry 4). | 0 | | | | | ✓ | |
| 17 | " scattering | " | 0 | | | | | ✓ | |
| 18 | " absorption | " | 0 | | | | | ✓ | |
| 19 | Surface object with surface sensor via stimulated emission | Raman spect., laser fluor., X-ray fluor. should have been identified. Chromatography, Ion selective membrane not applicable, Neutron activation for element identification. | 2 | 2 | | | ✓ | | ✓ |
| 20 | Surface object with surface sensor via spontaneous emission | Conventional emission spectroscopy should be added to data base. | 0 | 3 | 6 | | | ✓ | |
| 21 | Surface object with surface sensor via reflection | Visual examination. | 0 | 1 | | ✓ | | | |
| 22 | Surface object with surface sensor via refraction | Index of refraction measurement may provide clues as to origin. Instruments are inexpensive (see Key No. 155). | 1* | | | ✓ | | | ✓ |
| 23 | Surface object with surface sensor via scattering. | Turbidity measurement may be useful in water, otherwise clear-probably of limited utility however. | 0 | 1 | | | | | |
| 24 | Surface object with surface sensor via absorption | Conventional absorption spectrometers should be added to data base. | 3 | 2 | | ✓ | | | |
| 25 | Underwater object with surface sensor via stimulated emission | Same remarks as 19 with underwater samples. Impractical Impractical without sampling. | 2 | 1 | | ✓ | | | |
| 26 | Underwater object with surface sensor via spontaneous emission | With samples, see note 20. | 0 | 3 | 4 | ✓ | | | |
| 27 | Underwater object with surface sensor via reflection | Need samples, then above comments apply. | 0 | | | ✓ | | | |
| 28 | " refraction | " | 0 | | | | | | |
| 29 | " scattering | " | 0 | | | ✓ | | | |
| 30 | " absorption | " | 2 | 1 | | | | | |
| 31 | Bottom object by surface sensor via stimulated emission | Need samples, then above comments apply. | 0 | | | ✓ | | | |
| 32 | " spontaneous emission | " | 0 | | 5 | ✓ | | | |
| 33 | " reflection | " | 0 | | | ✓ | | | |
| 34 | " refraction | " | 0 | | | ✓ | | | |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

R - RELEVANT SENSORS FOUND, C - CLOSE TECHNOLOGY, N.R. - TECH. NOT REL., E - EXISTING TECH, OK, D - SPECIFIC DEVOPMENT REQ, N - NEW TECH REQ

FIG. A.6. MORPHOLOGICAL ANALYSIS — OIL SPILL CLASSIFICATION

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 35 | Bottom object by surface sensor via scattering | Need samples, then above comments apply. | 0 | | | ✓ | | | |
| 36 | " absorption | " | 0 | | | ✓ | | | |
| 37 | Surface object by underwater sensor via stimulated emission | Not practical. | 1 | | | ✓ | | | |
| 38 | " spontaneous emission | " | 0 | 3 | 3 | | | | |
| 39 | " reflection | " | 0 | | | | | | |
| 40 | " refraction | " | 0 | | | | | | |
| 41 | " scattering | " | 0 | | | | | | |
| 42 | " absorption | " | 0 | | | | | | |
| 43 | Underwater object by underwater sensor via stimulated emission | Laser fluor., neutron activation. | 1 | 3 | 2 | ✓ | | | |
| 44 | Underwater object by underwater sensor via spontaneous emission | Not practical. | 0 | 5 | 30 | | | | |
| 45 | Underwater object by underwater sensor via reflection | " | 0 | | 3 | | | | |
| 46 | " refraction | " | 0 | | 1 | | | | |
| 47 | " scattering | Laser absorption meter, Nephelometers | 2 | 3 | 5 | ✓ | ✓ | | |
| 48 | " absorption | Laser absorption, Gamma ray transmission | 3 | 3 | 5 | ✓ | | | |
| 49 | Bottom object by underwater sensor via stimulated emission | Laser fluor., X-ray fluor., Neutron activation. | 1 | | | ✓ | | | |
| 50 | " spontaneous emission | Not practical. | 0 | 2 | 7 | | | | |
| 51 | " reflection | " | 0 | | 2 | | | | |
| 52 | " refraction | " | 0 | | 1 | | | | |
| 53 | " scattering | " | 0 | | | | | | |
| 54 | " absorption | " | 0 | | | | | | |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

R - RELEVANT SENSORS FOUND, C - CLOSE TECHNOLOGY, N.R. - TECH. NOT REL., E - EXISTING TECH, OK, D - SPECIFIC DEVOPMENT REQ, N - NEW TECH REQ

# FIG. A.7. RESIDUAL MORPHOLOGY OFFSHORE LAW ENFORCEMENT

SEARCH OVER THE FOLLOWING

---ENVIRONMENT DESCRIPTORS---
6.1 AT SENSOR
 .AIR
 .SURFACE
 .UNDERWATER
 .BOTTOM
6.2 AT OBJECT
 .SURFACE
 .UNDERWATER
6.4 SENSOR OBJECT PROXIMITY
 .REMOTE

---OBJECT DESCRIPTORS---
7.1 NATURE OF OBJECT SENSED
 DISCRETE OBJECT
 .SOLID(DISC.)
7.2 OBJECT-STIMULUS INTERACTION
 ACTIVE OBJECT
 .SPONTANEOUS EMISS.
 PASSIVE OBJECT
 .REFLECTION
 .FIELD PERTURBATION
7.3 OBJECT INFORMATION
 SYNOPTIC INFO.
 .DETECT PRESENCE
 .IDENTIFY FEATURES

| | ENV. AT SENSOR | ENV. AT OBJECT | PROXIMITY | OBJECT SENSED | INTERACTION | OBJECT INFO. | | |
|---|---|---|---|---|---|---|---|---|
| | 1 AIR | SURFACE | REMOTE | SOLID(DISC.) | SPONTANEOUS EMISS. | DETECT PRESENCE | 64 | 12 |
| 0 | 132 133 158 212 213 234 235 | | | | | | | |
| | 2 AIR | SURFACE | REMOTE | SOLID(DISC.) | SPONTANEOUS EMISS. | IDENTIFY FEATURES | 6 | 17 |
| | 64 120 158 213 | | | | | | | |
| | 3 AIR | SURFACE | REMOTE | SOLID(DISC.) | REFLECTION | DETECT PRESENCE | 120 | 21 |
| 4 | 229 230 231 245 260 | | | | | | | |
| | 4 AIR | SURFACE | REMOTE | SOLID(DISC.) | REFLECTION | IDENTIFY FEATURES | 94 | 12 |
| 0 | 214 229 231 245 | | | | | | | |
| | 5 AIR | SURFACE | REMOTE | SOLID(DISC.) | FIELD PERTURBATION | DETECT PRESENCE | 27 | 21 |
| 2 | 220 | | | | | | | |
| | 6 AIR | SURFACE | REMOTE | SOLID(DISC.) | FIELD PERTURBATION | IDENTIFY FEATURES | | |
| | 7 AIR | UNDERWATER | REMOTE | SOLID(DISC.) | SPONTANEOUS EMISS. | DETECT PRESENCE | (64) | 13 |
| 2 | 133 (212) (215) 267 | | | | | | | |
| | 8 AIR | UNDERWATER | REMOTE | SOLID(DISC.) | SPONTANEOUS EMISS. | IDENTIFY FEATURES | (64) | |
| | 9 AIR | UNDERWATER | REMOTE | SOLID(DISC.) | REFLECTION | DETECT PRESENCE | 89 | 27 |
| 0 | 273 230 | | | | | | | |
| | 10 AIR | UNDERWATER | REMOTE | SOLID(DISC.) | REFLECTION | IDENTIFY FEATURES | 94 | |
| | 11 AIR | UNDERWATER | REMOTE | SOLID(DISC.) | FIELD PERTURBATION | DETECT PRESENCE | 27 | 11 |
| 9 | 212 216 | | | | | | | |
| | 12 AIR | UNDERWATER | REMOTE | SOLID(DISC.) | FIELD PERTURBATION | IDENTIFY FEATURES | | |
| | 13 SURFACE | SURFACE | REMOTE | SOLID(DISC.) | SPONTANEOUS EMISS. | DETECT PRESENCE | 132 | 13 |
| 3 | 158 212 234 237 | | | | | | | |
| | 14 SURFACE | SURFACE | REMOTE | SOLID(DISC.) | SPONTANEOUS EMISS. | IDENTIFY FEATURES | 158 | |
| | 15 SURFACE | SURFACE | REMOTE | SOLID(DISC.) | REFLECTION | DETECT PRESENCE | 93 | |
| | 16 SURFACE | SURFACE | REMOTE | SOLID(DISC.) | REFLECTION | IDENTIFY FEATURES | | |
| | 17 SURFACE | SURFACE | REMOTE | SOLID(DISC.) | FIELD PERTURBATION | DETECT PRESENCE | 212 | |
| | 18 SURFACE | SURFACE | REMOTE | SOLID(DISC.) | FIELD PERTURBATION | IDENTIFY FEATURES | | |
| | 19 SURFACE | UNDERWATER | REMOTE | SOLID(DISC.) | SPONTANEOUS EMISS. | DETECT PRESENCE | 132 | 13 |
| 3 | (212) (237) 263 264 | | | | | | | |
| | 20 SURFACE | UNDERWATER | REMOTE | SOLID(DISC.) | SPONTANEOUS EMISS. | IDENTIFY FEATURES | | |
| | 21 SURFACE | UNDERWATER | REMOTE | SOLID(DISC.) | REFLECTION | DETECT PRESENCE | | |
| | 22 SURFACE | UNDERWATER | REMOTE | SOLID(DISC.) | REFLECTION | IDENTIFY FEATURES | | |
| | 23 SURFACE | UNDERWATER | REMOTE | SOLID(DISC.) | FIELD PERTURBATION | DETECT PRESENCE | 212 | |
| | 24 SURFACE | UNDERWATER | REMOTE | SOLID(DISC.) | FIELD PERTURBATION | IDENTIFY FEATURES | | |
| | 25 UNDERWATER | SURFACE | REMOTE | SOLID(DISC.) | SPONTANEOUS EMISS. | DETECT PRESENCE | (132) | (13 |
| 3) | 207 (212) 272 237 | | | | | | | |
| | 26 UNDERWATER | SURFACE | REMOTE | SOLID(DISC.) | SPONTANEOUS EMISS. | IDENTIFY FEATURES | | |

## FIG. A.7. *(Cont.)*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 27 3 | UNDERWATER | SURFACE | REMOTE | SOLID(DISC.) | REFLECTION | DETECT PRESENCE | |
| 28 4 | UNDERWATER | SURFACE | REMOTE | SOLID(DISC.) | REFLECTION | IDENTIFY FEATURES | 94 |
| 29 5 | UNDERWATER | SURFACE | REMOTE | SOLID(DISC.) | FIELD PERTURBATION | DETECT PRESENCE | 212 |
| 30 6 | UNDERWATER | SURFACE | REMOTE | SOLID(DISC.) | FIELD PERTURBATION | IDENTIFY FEATURES | |
| 31 7 | UNDERWATER | UNDERWATER | REMOTE | SOLID(DISC.) | SPONTANEOUS EMISS. | DETECT PRESENCE | 24 29 |
| (132) (133) 207 209 210 212 215 272 274 275 278 237 251 252 255 258 261 263 264 | | | | | | | |
| 32 8 | UNDERWATER | UNDERWATER | REMOTE | SOLID(DISC.) | SPONTANEOUS EMISS. | IDENTIFY FEATURES | 209 21 |
| 0 275 255 258 | | | | | | | |
| 33 9 | UNDERWATER | UNDERWATER | REMOTE | SOLID(DISC.) | REFLECTION | DETECT PRESENCE | 76 10 |
| 1 128 142 152 171 174 175A 273 276 238 241 265 266 | | | | | | | |
| 34 10 | UNDERWATER | UNDERWATER | REMOTE | SOLID(DISC.) | REFLECTION | IDENTIFY FEATURES | 88 10 |
| 1 94 112 114 122 125 152 171 174 238 241 265 266 | | | | | | | |
| 35 11 | UNDERWATER | UNDERWATER | REMOTE | SOLID(DISC.) | FIELD PERTURBATION | DETECT PRESENCE | 212 21 |
| 5 274 252 | | | | | | | |
| 36 12 | UNDERWATER | UNDERWATER | REMOTE | SOLID(DISC.) | FIELD PERTURBATION | IDENTIFY FEATURES | 125 |
| 37 13 | BOTTOM | SURFACE | REMOTE | SOLID(DISC.) | SPONTANEOUS EMISS. | DETECT PRESENCE | (132) (13 |
| 3) 272 | | | | | | | |
| 38 14 | BOTTOM | SURFACE | REMOTE | SOLID(DISC.) | SPONTANEOUS EMISS. | IDENTIFY FEATURES | |
| 39 15 | BOTTOM | SURFACE | REMOTE | SOLID(DISC.) | REFLECTION | DETECT PRESENCE | |
| 40 16 | BOTTOM | SURFACE | REMOTE | SOLID(DISC.) | REFLECTION | IDENTIFY FEATURES | |
| 41 17 | BOTTOM | SURFACE | REMOTE | SOLID(DISC.) | FIELD PERTURBATION | DETECT PRESENCE | |
| 42 18 | BOTTOM | SURFACE | REMOTE | SOLID(DISC.) | FIELD PERTURBATION | IDENTIFY FEATURES | |
| 43 19 | BOTTOM | UNDERWATER | REMOTE | SOLID(DISC.) | SPONTANEOUS EMISS. | DETECT PRESENCE | (132) (13 |
| 3) 272 275 252 | | | | | | | |
| 44 20 | BOTTOM | UNDERWATER | REMOTE | SOLID(DISC.) | SPONTANEOUS EMISS. | IDENTIFY FEATURES | 275 |
| 45 21 | BOTTOM | UNDERWATER | REMOTE | SOLID(DISC.) | REFLECTION | DETECT PRESENCE | |
| 46 22 | BOTTOM | UNDERWATER | REMOTE | SOLID(DISC.) | REFLECTION | IDENTIFY FEATURES | |
| 47 23 | BOTTOM | UNDERWATER | REMOTE | SOLID(DISC.) | FIELD PERTURBATION | DETECT PRESENCE | 252 |
| 48 24 | BOTTOM | UNDERWATER | REMOTE | SOLID(DISC.) | FIELD PERTURBATION | IDENTIFY FEATURES | |

FIG. A.8. MORPHOLOGICAL ANALYSIS — OFFSHORE LAW ENFORCEMENT

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS R | C | NR | INDICATED TECH E | D | N | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Detection of surface vessels from aircraft (airships) (self-emission) | Detectors of IR and EM radiation | 7 | 2 | | ✓ | | | |
| 2 | Determine features of surface vessels from aircraft (self-emission) | IR and microwave imagery | 5 | 1 | | ✓ | | | |
| 3 | Detection of surface vessels from aircraft (reflected energy) | Radar and visual sensors | 7 | | | ✓ | | | |
| 4 | Determine features of surface vessels from aircraft (reflected energy) | High resolution radar, TV and film photography, Synthetic Aperture Radar | 5 | 1 | | ✓ | ✓ | | ✓ |
| 5 | Detection of surface vessels from aircraft (field perturbation) | Magnetometers and gradiometers, pulsed magnetic field sensor | 3 | | | ✓ | | | |
| 6 | Determine features of surface vessels from aircraft (field perturbation) | Magnetic anomaly signature | 0 | | | | ✓ | | |
| 7 | Detection of submersibles (submerged* objects) from aircraft (self-emission) | Detection of surface IR effects (shallow subs only), residual wake detector (sonobuoy intermediate sensors with radio link to aircraft) | 1 | 2 | 3 | | ✓ | ✓ | |
| 8 | Determine features of submersibles from aircraft (self-emission) | Not presently feasible without intermediate sensor at surface | 0 | | 1 | | | ✓ | |
| 9 | Detection of submersibles (submerged objects) from aircraft (reflection) | LIDAR (laser-radar), optical photography, narrow spectrum TV (shallow sub) | 4 | | | ✓ | | | |
| 10 | Determine features of submersibles from aircraft (reflection) | TV and optical photography (shallow subs) | 1 | | | ✓ | ✓ | | |
| 11 | Detection of submersibles from aircraft (field perturbation) | Magnetic anomaly detectors, pulsed magnetic field sensor (key 220) | 4 | | | ✓ | | | |
| 12 | Identify features of submersibles from aircraft (field perturbation) | Improve MAD gear to detect anomaly signature characteristics Detect moving anomaly from moving sensor | 0 | | | | ✓ | | |
| 13 | Detection of surface vessels from surface-based sensors (self-emission) | Detection of light or radio emissions, IR, FLIR sensors | 4 | 1 | | ✓ | | | |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

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FIG. A.8. MORPHOLOGICAL ANALYSIS — OFFSHORE LAW ENFORCEMENT

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 14 | Identify features of surface vessel from surface sensor (self-emission) | IR imagery | 1 | | | ✓ | | | |
| 15 | Detection of surface vessels from surface sensor (reflection) | Radar, optical sensors, visual aide, IR searchlight and FLIR | 1 | | | ✓ | | | |
| 16 | Identify features of surface vessel from surface sensor (reflection) | High resolution radar, optical imagery, IR searchlight and FLIR (see key 120, 158, 214) | 3* | | | ✓ | | | |
| 17 | Detection of surface vessels from a surface sensor (field perturbation) | Magnetometer on buoy, structure or non-magnetic vessel Bistatic radar (forward scattering) | 1 | | | ✓ | ✓ | ✓ | ✓ |
| 18 | Identify features of surface vessel from surface sensor (field perturbation) | MAD signature resolution, EM holography | 0 | | | | ✓ | ✓ | |
| 19 | Detection of submersibles from a surface sensor (self emission) | Detection of external lights, radio emissions (near surface), acoustic radiation detection (sensor just beneath surface), sonobuoys | 3 | 1 | 2 | ✓ | | | |
| 20 | Identify features of submersibles from a surface sensor (self-emission) | No practical method known (passive sonar considered in line 31) | 0 | | | | | ✓ | |
| 21 | Detection of submersible from a surface sensor (reflection) | LIDAR (shallow sub), active sonar (sensor just below surface) (see key Nrs. 270, 273, 276, 268) | 4* | | | ✓ | | | ✓ |
| 22 | Identify features of submersible from a surface sensor (reflection) | LIDAR (shallow-sub) (see key Nrs. 270, 273) | 2* | | | ✓ | | | |
| 23 | Detection of a submersible by a surface sensor (field perturbation) | MAD equipment, pulsed magnetic field sensor (key 220) | 1 | | | ✓ | | | |
| 24 | Identify features of submersible by a surface sensor (field perturbation) | MAD-signature resolution | 0 | | | | ✓ | | |
| 25 | Detection of surface vessel by underwater sensor (self-emission) | Passive acoustic sensors, sonobuoys, optical detection of light beacon | 3 | | 3 | ✓ | | | |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

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FIG. A.8. MORPHOLOGICAL ANALYSIS — OFFSHORE LAW ENFORCEMENT

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 26 | Identify features of surface vessel by underwater sensor (self-emission) | Acoustic signature classifications (key Nrs. 275, 251) | 2* | | | ✓ | | | |
| 27 | Detection of surface vessel by underwater sensor (reflection) | Active sonar, optical sensors (clear water) (key Nr. 114, 174) | 2* | | | ✓ | | | |
| 28 | Identify features of surface vessel by underwater sensor (reflection) | Optical imaging (clear water), high resolution active sonar (key 174) | 1 | | | ✓ | | | |
| 29 | Detection of surface vessel by underwater sensor (field perturbation) | MAD equipment, buoy mounted on tow-body | 1 | | | ✓ | | | |
| 30 | Identify features of surface vessel by underwater sensor (field perturbation) | MAD-signature resolution | 0 | | | | | | |
| 31 | Detection of submersible by underwater sensors (self-emission) | Passive acoustic receivers, sonobuoys, optical detector for light beacon | 15 | 4 | 2 | ✓ | | | |
| 32 | Identify features of submersible by underwater sensor (self-emission) | Acoustic signature classification | 5 | | | ✓ | | | |
| 33 | Detection of submersible by underwater sensor (reflection) | LIDAR (clear water) active sonar | 12 | 2 | | ✓ | | | |
| 34 | Identify features of submersible by underwater sensor (reflection) | Optical imaging (clear water), acoustic imaging | 12 | 2 | | ✓ | | | |
| 35 | Detection of submersible by underwater sensor (field perturbation) | MAD equipment, buoy mounted or on tow body | 3 | 1 | | ✓ | | | |
| 36 | Identify features of submersible by underwater sensor (field perturbation) | Acoustic holography | 1 | | | ✓ | | | |
| 37 | Detection of surface vessel by sensor on bottom (self-emission) | Passive acoustic detection sensors | 1 | | 2 | ✓ | | | |
| 38 | Identify features of surface vessel with bottom sensors (self-emission) | Acoustic signature classification (see key Nrs. 275, 251) | 2* | | | ✓ | | | |

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**DATA BASE ADDITION NEEDED

R - RELEVANT SENSORS FOUND, C - CLOSE TECHNOLOGY, N.R. - TECH. NOT REL., E - EXISTING TECH, OK, D - SPECIFIC DEVOPMENT REQ, N - NEW TECH REQ

FIG. A.8. MORPHOLOGICAL ANALYSIS — OFFSHORE LAW ENFORCEMENT

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 39 | Detection of surface vessel by sensor on bottom (reflection) | Active, bottom mounted sonar | 0 | | | | ✓ | | |
| 40 | Identify features of surface vessel with bottom sensor (reflection) | High resolutions, bottom mounted active sonar | 0 | | | | ✓ | | |
| 41 | Detection of surface vessel by sensor on bottom (field perturbation) | MAD equipment, bottom mounted, magnetic cable barrier or bottom | 0 | | | | ✓ | | ✓ |
| 42 | Identify features of surface vessel with bottom sensor (field perturbation) | Vessel size determination with pulsed magnetic field | 0 | | | | ✓ | ✓ | ✓ |
| 43 | Detection of submersible by sensor on bottom (self-emission) | Passive acoustic sensors | 2 | 1 | 2 | ✓ | | | |
| 44 | Identify features of submersible with sensor on bottom (self-emission) | Acoustic signature classification | 1 | | | ✓ | | | |
| 45 | Detection of submersible by sensor on bottom (reflection) | Active bottom-mounted sonar | 0 | | | | ✓ | | |
| 46 | Identify features of submersible with sensor on bottom (reflection) | High resolution, active sonar | 0 | | | | ✓ | | |
| 47 | Detection of submersible by sensor on bottom (field perturbation) | MAD equipment, magnetic cable barrier type sensor | 1 | | | | ✓ | | ✓ |
| 48 | Identify features of submersible with sensor on bottom (field perturbation) | Vessel size determination with pulsed magnetic field | 0 | | | | ✓ | ✓ | ✓ |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

R - RELEVANT SENSORS FOUND, C - CLOSE TECHNOLOGY, N.R. - TECH. NOT REL., E - EXISTING TECH, OK, D - SPECIFIC DEVOPMENT REQ, N - NEW TECH REQ

## FIG. A.9. RESIDUAL MORPHOLOGY, ICE MEASUREMENT AND MAPPING

SEARCH OVER THE FOLLOWING
RESIDUAL MORPHOLOGY, ICE MEASUREMENT AND MAPPING. 1/19/78

---SENSOR DESCRIPTORS---
5.4 STIMULUS USED
    ACOUSTIC
        .H.F. SOUND
    FORCE FIELD
        .MAGNETIC
    ELECTROMAGNETIC
        .LIGHT
        .MICROWAVES

---ENVIRONMENT DESCRIPTORS---
6.1 AT SENSOR
        .SPACE
        .AIR
        .SURFACE
        .UNDERWATER
6.2 AT OBJECT
        .SURFACE

---OBJECT DESCRIPTORS---
7.1 NATURE OF OBJECT SENSED
    DISCRETE OBJECT
        .SOLID(DISC.)
7.3 OBJECT INFORMATION
    SYNOPTIC INFO.
        .DETECT PRESENCE
        .IDENTIFY FEATURES
        .MEASURE PROPERTIES
    GEOMETRIC INFO.
        .2-D SURFACE IMAGE

| | STIMULUS USED | ENV. AT SENSOR | ENV. AT OBJECT | OBJECT SENSED | OBJECT INFO. | |
|---|---|---|---|---|---|---|
| 1 | H.F. SOUND | SPACE | SURFACE | SOLID(DISC.) | DETECT PRESENCE | |
| 2 | H.F. SOUND | SPACE | SURFACE | SOLID(DISC.) | IDENTIFY FEATURES | |
| 3 | H.F. SOUND | SPACE | SURFACE | SOLID(DISC.) | MEASURE PROPERTIES | |
| 4 | H.F. SOUND | SPACE | SURFACE | SOLID(DISC.) | 2-D SURFACE IMAGE | |
| 5 | H.F. SOUND | AIR | SURFACE | SOLID(DISC.) | DETECT PRESENCE | |
| 6 | H.F. SOUND | AIR | SURFACE | SOLID(DISC.) | IDENTIFY FEATURES | |
| 7 | H.F. SOUND | AIR | SURFACE | SOLID(DISC.) | MEASURE PROPERTIES | |
| 8 | H.F. SOUND | AIR | SURFACE | SOLID(DISC.) | 2-D SURFACE IMAGE | |
| 9 | H.F. SOUND | SURFACE | SURFACE | SOLID(DISC.) | DETECT PRESENCE | |
| 10 | H.F. SOUND | SURFACE | SURFACE | SOLID(DISC.) | IDENTIFY FEATURES | |
| 11 | H.F. SOUND | SURFACE | SURFACE | SOLID(DISC.) | MEASURE PROPERTIES | |
| 12 | H.F. SOUND | SURFACE | SURFACE | SOLID(DISC.) | 2-D SURFACE IMAGE | |
| 13 | H.F. SOUND | UNDERWATER | SURFACE | SOLID(DISC.) | DETECT PRESENCE | 272 |
| 14 | H.F. SOUND | UNDERWATER | SURFACE | SOLID(DISC.) | IDENTIFY FEATURES | |
| 15 | H.F. SOUND | UNDERWATER | SURFACE | SOLID(DISC.) | MEASURE PROPERTIES | |
| 16 | H.F. SOUND | UNDERWATER | SURFACE | SOLID(DISC.) | 2-D SURFACE IMAGE | |
| 17 | MAGNETIC | SPACE | SURFACE | SOLID(DISC.) | DETECT PRESENCE | |
| 18 | MAGNETIC | SPACE | SURFACE | SOLID(DISC.) | IDENTIFY FEATURES | |
| 19 | MAGNETIC | SPACE | SURFACE | SOLID(DISC.) | MEASURE PROPERTIES | |
| 20 | MAGNETIC | SPACE | SURFACE | SOLID(DISC.) | 2-D SURFACE IMAGE | |
| 21 | MAGNETIC | AIR | SURFACE | SOLID(DISC.) | DETECT PRESENCE | (27) (212) 220 |
| 22 | MAGNETIC | AIR | SURFACE | SOLID(DISC.) | IDENTIFY FEATURES | |
| 23 | MAGNETIC | AIR | SURFACE | SOLID(DISC.) | MEASURE PROPERTIES | (212) (219) 220 |

FIG. A.9. Cont.)

| | | | | | | |
|---|---|---|---|---|---|---|
| 24 | MAGNETIC | AIR | SURFACE | SOLID(DISC.) | 2-D SURFACE IMAGE | |
| 25 | MAGNETIC | SURFACE | SURFACE | SOLID(DISC.) | DETECT PRESENCE | (212) |
| 26 | MAGNETIC | SURFACE | SURFACE | SOLID(DISC.) | IDENTIFY FEATURES | |
| 27 | MAGNETIC | SURFACE | SURFACE | SOLID(DISC.) | MEASURE PROPERTIES | (212) (219) |
| 28 | MAGNETIC | SURFACE | SURFACE | SOLID(DISC.) | 2-D SURFACE IMAGE | |
| 29 | MAGNETIC | UNDERWATER | SURFACE | SOLID(DISC.) | DETECT PRESENCE | (212) |
| 30 | MAGNETIC | UNDERWATER | SURFACE | SOLID(DISC.) | IDENTIFY FEATURES | |
| 31 | MAGNETIC | UNDERWATER | SURFACE | SOLID(DISC.) | MEASURE PROPERTIES | (212) (219) |
| 32 | MAGNETIC | UNDERWATER | SURFACE | SOLID(DISC.) | 2-D SURFACE IMAGE | |
| 33 | LIGHT | SPACE | SURFACE | SOLID(DISC.) | DETECT PRESENCE | 132 133 |
| 34 | LIGHT | SPACE | SURFACE | SOLID(DISC.) | IDENTIFY FEATURES | 148A |
| 35 | LIGHT | SPACE | SURFACE | SOLID(DISC.) | MEASURE PROPERTIES | 132 133 (148A) 201 |
| 36 | LIGHT | SPACE | SURFACE | SOLID(DISC.) | 2-D SURFACE IMAGE | 5 148A (165) 201 |
| 37 | LIGHT | AIR | SURFACE | SOLID(DISC.) | DETECT PRESENCE | 64 120 132 133 158 21 |
| 3 230 (231) | | | | | | |
| 38 | LIGHT | AIR | SURFACE | SOLID(DISC.) | IDENTIFY FEATURES | 64 94 120 158 213 (23 |
| 1) | | | | | | |
| 39 | LIGHT | AIR | SURFACE | SOLID(DISC.) | MEASURE PROPERTIES | 132 133 202 230 |
| 40 | LIGHT | AIR | SURFACE | SOLID(DISC.) | 2-D SURFACE IMAGE | 64 94 120 158 (165) 20 |
| 2 213 (231) | | | | | | |
| 41 | LIGHT | SURFACE | SURFACE | SOLID(DISC.) | DETECT PRESENCE | 132 133 158 (237) |
| 42 | LIGHT | SURFACE | SURFACE | SOLID(DISC.) | IDENTIFY FEATURES | 158 |
| 43 | LIGHT | SURFACE | SURFACE | SOLID(DISC.) | MEASURE PROPERTIES | 132 133 |
| 44 | LIGHT | SURFACE | SURFACE | SOLID(DISC.) | 2-D SURFACE IMAGE | 158 |
| 45 | LIGHT | UNDERWATER | SURFACE | SOLID(DISC.) | DETECT PRESENCE | (132)(133)(237) |
| 46 | LIGHT | UNDERWATER | SURFACE | SOLID(DISC.) | IDENTIFY FEATURES | 94 |
| 47 | LIGHT | UNDERWATER | SURFACE | SOLID(DISC.) | MEASURE PROPERTIES | (132) (133) |
| 48 | LIGHT | UNDERWATER | SURFACE | SOLID(DISC.) | 2-D SURFACE IMAGE | 94 |
| 49 | MICROWAVES | SPACE | SURFACE | SOLID(DISC.) | DETECT PRESENCE | (229) 245 |
| 50 | MICROWAVES | SPACE | SURFACE | SOLID(DISC.) | IDENTIFY FEATURES | (245) |
| 51 | MICROWAVES | SPACE | SURFACE | SOLID(DISC.) | MEASURE PROPERTIES | |
| 52 | MICROWAVES | SPACE | SURFACE | SOLID(DISC.) | 2-D SURFACE IMAGE | 245 |
| 53 | MICROWAVES | AIR | SURFACE | SOLID(DISC.) | DETECT PRESENCE | 214 229 231 245 (260) |
| 54 | MICROWAVES | AIR | SURFACE | SOLID(DISC.) | IDENTIFY FEATURES | 17 214 229 (231) 245 |
| 55 | MICROWAVES | AIR | SURFACE | SOLID(DISC.) | MEASURE PROPERTIES | 91 92 192 |
| 56 | MICROWAVES | AIR | SURFACE | SOLID(DISC.) | 2-D SURFACE IMAGE | 17 91 92 214 229 23 |
| 1 245 | | | | | | |
| 57 | MICROWAVES | SURFACE | SURFACE | SOLID(DISC.) | DETECT PRESENCE | |
| 58 | MICROWAVES | SURFACE | SURFACE | SOLID(DISC.) | IDENTIFY FEATURES | |
| 59 | MICROWAVES | SURFACE | SURFACE | SOLID(DISC.) | MEASURE PROPERTIES | |
| 60 | MICROWAVES | SURFACE | SURFACE | SOLID(DISC.) | 2-D SURFACE IMAGE | |
| 61 | MICROWAVES | UNDERWATER | SURFACE | SOLID(DISC.) | DETECT PRESENCE | |
| 62 | MICROWAVES | UNDERWATER | SURFACE | SOLID(DISC.) | IDENTIFY FEATURES | |
| 63 | MICROWAVES | UNDERWATER | SURFACE | SOLID(DISC.) | MEASURE PROPERTIES | |
| 64 | MICROWAVES | UNDERWATER | SURFACE | SOLID(DISC.) | 2-D SURFACE IMAGE | |

FIG. A.10. MORPHOLOGICAL ANALYSIS — ICE MEASUREMENT AND MAPPING

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS R | DATA BASE SENSORS C | DATA BASE SENSORS NR | INDICATED TECH E | INDICATED TECH D | INDICATED TECH N | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| 1-3 | Sonar Arrays map ice at narrows in passages, relay to satellite. | Underwater active arrays. Surface microwave station. Satellite receiver. | | | | | ✓ | | ✓ |
| 4 | Multiple arrays installed in the configuration above. | As above, plus computer facility to convert to 2-D image. | | | | | ✓ | | ✓ |
| 5 | N.A. | | | | | | | | |
| 6-7 | Airborne launch of detector measures ice thickness, character. Relay to plane. | Expendable acoustic active systems, operating at surface. Radio relay. | | | | | | ✓ | |
| 8 | N.A. | | | | | | | | |
| 9 | N.A. | | | | | | | | |
| 10-11 | Surface vehicle survey of critical navigation areas or near ice breaker | Acoustic active device measures ice thickness, ice properties | | | | | | ✓ | ✓ |
| 12 | N.A. | | | | | | | | |
| 13 | Permanent buoys monitor ambient noise in relation ice buildup | Passive acoustic detectors. Radio relay. | 1 | | | | ✓ | | ✓ |
| 13-15 | Submarine-mounted upward-looking sonar seeks hole or weak ice for surfacing | High resolution sonar. | | 1** | | ✓ | | | |
| 16 | Relate underwater ice contours to ice characteristics with submarine measurements | High resolution sonar. Computerized data storage with contour plot. | | 1** | | ✓ | | | ✓ |
| 17 | N.A. | | | | | | | | |
| 18-19 | Detection ice thickness synoptically by magnetic sensors placed on ice surface. Relay to satellite. | Magnetic eddy current device (220). Microwave relay. | | | | ✓ | | | |
| 20 | N.A. | | | | | | | | |
| 21 | Airborne measurement of ice presence, thickness along plane track. | Magnetic-eddy current device (220). | 1 | | 2 | | ✓ | | ✓ |
| 22 | As above. | Plot of ice thickness vs distance along track to identify type of ice. | | | | | ✓ | | ✓ |
| 23 | As in 21. | | 1 | | 2 | | | | |
| 24 | As in 21, except airplane flies grid over desired surface area | Magnetic eddy current device measures ice thickness. | | | | | ✓ | | ✓ |
| | | | | | | | | | |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

R - RELEVANT SENSORS FOUND, C - CLOSE TECHNOLOGY, N.R. - TECH. NOT REL., E - EXISTING TECH, OK, D - SPECIFIC DEVOPMENT REQ, N - NEW TECH REQ

FIG. A.10. MORPHOLOGICAL ANALYSIS — ICE MEASUREMENT AND MAPPING

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 25 | N.A. | | | | | | | | |
| 26 | N.A. | | | | 1 | | | | |
| 27 | Thickness detectors deployed on ice surface give synoptic readouts. | Magnetic eddy current. Radio relay. | | | 2 | | ✓ | | |
| 28 | Map display using many devices found in 27 | | | | | | ✓ | | |
| 29 | N.A. | | | | 1 | | | | |
| 31 | N.A. | | | | 2 | | | | |
| 30,32 | N.A. | | | | | | | | |
| 33 | Map areas of occurrence and non-occurrence of ice from space | Satellite IR detectors. Requires spatial scanning system. | 2 | | | ✓ | ✓ | | ✓ |
| 34 | Map areas for occurrence and types of ice from space. | Satellite mounted optical devices. | 1 | | | | ✓ | | ✓ |
| 35 | Map areas for ice thickness | Satellite mounted IR detectors. | 3 | | 1 | | ✓ | | ✓ |
| 36 | 2-dimensional displays of mapping searches in 33-35 | See 33-35. | 3 | | 1 | | ✓ | | ✓ |
| 37 | Airborne determination of ice presence by optical and infrared means | Aerial photography. IR sensors. Spectral Analysis | 6 | | 1 | ✓ | ✓ | | |
| 38 | As in 37, plus determination of ice type | Aerial photography including spectrial analysis. IR sensors | 5 | | 1 | ✓ | ✓ | | ✓ |
| 39 | As in 37, plus determinaation of thickness, density | Optical spectral devices. IR sensors | 4 | | | ✓ | ✓ | | ✓ |
| 40 | As in 37, plus extensive maps. | Aerial photography. IR imaging. | 6 | | 2 | ✓ | ✓ | | ✓ |
| 41 | Placement optical installations near navigable narrows, sometimes ice-clogged. | IR detectors. | 3 | | 1 | ✓ | | | ✓ |
| 42 | As above, plus determine above-water shape or size. | IR detectors. Also scanning laser systems. | 1 | ** | | ✓ | ✓ | | ✓ |
| 43 | As above in 42. | | 2 | ** | | | | | ✓ |
| 44 | N.A. | | | | 1 | | | | |
| 45 | Optical observation underwater sections of ice from submarine | Visual detectors. | | ** | 3 | ✓ | | | ✓ |
| 46 | As in 45, plus estimate underwater shape. | Photographic | 1 | | | ✓ | | | ✓ |
| 47 | As in 45, plus determine ice type | | | | 2 | ✓ | ✓ | | ✓ |
| 48 | As in 45, plus delineation of underwater shape | Photographic | 1 | | | ✓ | ✓ | | ✓ |
| 49 | Coarse mapping of ice presence from space with microwaves | Satellite-mounted radar | | 1 | 1 | | ✓ | | ✓ |
| 50 | N.A. | | | | 1 | | | | |
| 51 | N.A. | | | | | | | | |
| 52 | As in 49 | | | 1 | | | ✓ | | ✓ |

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**DATA BASE ADDITION NEEDED

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FIG. A.10. MORPHOLOGICAL ANALYSIS — ICE MEASUREMENT AND MAPPING

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 53 | Airborne detection of ice with microwaves, e.g., searching for passage | Aircraft radar. | 2 | 2 | 1 | ✓ | ✓ | | ✓ |
| 54 | As above, plus characterize above-water shape. | " | 4 | | 1 | ✓ | ✓ | | ✓ |
| 55 | As in 53, plus measure thickness | " | 3 | | | ✓ | ✓ | | ✓ |
| 56 | As in 53, plus mapping of ice-covered areas | " Computerized analysis to yield maps. Or microwave emission | 5 | 2 | | ✓ | ✓ | | ✓ |
| 57 | Permanent microwave installations near navigable narrows sometimes ice-clogged | Radar (fixed) | ** | | | ✓ | | | ✓ |
| 58 | As above, plus characterize above-water shape | Radar | ** | | | ✓ | | | ✓ |
| 59,60 | N.A. | | | | | | | | |
| 61-64 | N.A. | | | | | | | | |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

R - RELEVANT SENSORS FOUND, C - CLOSE TECHNOLOGY, N.R. - TECH. NOT REL., E - EXISTING TECH, OK, D - SPECIFIC DEVOPMENT REQ, N - NEW TECH REQ

## FIG. A.11. RESIDUAL MORPHOLOGY — HELICOPTER-AIDED ICEBREAKING

SEARCH OVER THE FOLLOWING
RESIDUAL MORPHOLOGY. HELICOPTER-AIDED ICEBREAKING. 1/19/78

---SENSOR DESCRIPTORS--
5.4 STIMULUS USED
- ACOUSTIC
  - .H.F. SOUND
- FORCE FIELD
  - .MAGNETIC
- ELECTROMAGNETIC
  - .LIGHT
  - .MICROWAVES

---ENVIRONMENT DESCRIPTORS---
6.1 AT SENSOR
- .AIR
- .SURFACE
- .UNDERWATER

6.2 AT OBJECT
- .SURFACE
- .UNDERWATER

6.3 SENSOR PLATFORM
- .MOBILE, CONTROLLED

---OBJECT DESCRIPTORS---
7.1 NATURE OF OBJECT SENSED
- DISCRETE OBJECT
  - .SOLID(DISC.)

7.3 OBJECT INFORMATION
- SYNOPTIC INFO.
  - .DETECT PRESENCE
  - .MEASURE PROPERTIES
- GEOMETRIC INFO.
  - .2-D SURFACE IMAGE

| | STIMULUS USED | ENV. AT SENSOR | ENV. AT OBJECT | SENSOR PLATFORM | OBJECT SENSED | OBJECT INFO. | |
|---|---|---|---|---|---|---|---|
| 1 | H.F. SOUND | AIR | SURFACE | MOBILE, CONTROLLED | SOLID(DISC.) | DETECT PRESENCE | |
| 2 | H.F. SOUND | AIR | SURFACE | MOBILE, CONTROLLED | SOLID(DISC.) | MEASURE PROPERTIES | |
| 3 | H.F. SOUND | AIR | SURFACE | MOBILE, CONTROLLED | SOLID(DISC.) | 2-D SURFACE IMAGE | |
| 4 | H.F. SOUND | AIR | UNDERWATER | MOBILE, CONTROLLED | SOLID(DISC.) | DETECT PRESENCE | |
| 5 | H.F. SOUND | AIR | UNDERWATER | MOBILE, CONTROLLED | SOLID(DISC.) | MEASURE PROPERTIES | |
| 6 | H.F. SOUND | AIR | UNDERWATER | MOBILE, CONTROLLED | SOLID(DISC.) | 2-D SURFACE IMAGE | |
| 7 | H.F. SOUND | SURFACE | SURFACE | MOBILE, CONTROLLED | SOLID(DISC.) | DETECT PRESENCE | |
| 8 | H.F. SOUND | SURFACE | SURFACE | MOBILE, CONTROLLED | SOLID(DISC.) | MEASURE PROPERTIES | |
| 9 | H.F. SOUND | SURFACE | SURFACE | MOBILE, CONTROLLED | SOLID(DISC.) | 2-D SURFACE IMAGE | |
| 10 | H.F. SOUND | SURFACE | UNDERWATER | MOBILE, CONTROLLED | SOLID(DISC.) | DETECT PRESENCE | (188) |
| 11 | H.F. SOUND | SURFACE | UNDERWATER | MOBILE, CONTROLLED | SOLID(DISC.) | MEASURE PROPERTIES | |
| 12 | H.F. SOUND | SURFACE | UNDERWATER | MOBILE, CONTROLLED | SOLID(DISC.) | 2-D SURFACE IMAGE | |
| 13 | H.F. SOUND | UNDERWATER | SURFACE | MOBILE, CONTROLLED | SOLID(DISC.) | DETECT PRESENCE | |
| 14 | H.F. SOUND | UNDERWATER | SURFACE | MOBILE, CONTROLLED | SOLID(DISC.) | MEASURE PROPERTIES | |
| 15 | H.F. SOUND | UNDERWATER | SURFACE | MOBILE, CONTROLLED | SOLID(DISC.) | 2-D SURFACE IMAGE | |
| 16 | H.F. SOUND | UNDERWATER | UNDERWATER | MOBILE, CONTROLLED | SOLID(DISC.) | DETECT PRESENCE | 101 14 |
| 2 | 152 (153) 174 175A (189) (277) | | | | | | |
| 17 | H.F. SOUND | UNDERWATER | UNDERWATER | MOBILE, CONTROLLED | SOLID(DISC.) | MEASURE PROPERTIES | (208) |
| 18 | H.F. SOUND | UNDERWATER | UNDERWATER | MOBILE, CONTROLLED | SOLID(DISC.) | 2-D SURFACE IMAGE | 34 10 |
| 1 | 142 152 174 175A | | | | | | |

FIG. A.11. *(Cont.)*

```
 19  MAGNETIC    AIR          SURFACE      MOBILE, CONTROLLED  SOLID(DISC.)   DETECT PRESENCE    (212) 22
0
 20  MAGNETIC    AIR          SURFACE      MOBILE, CONTROLLED  SOLID(DISC.)   MEASURE PROPERTIES (212) (21
9) 220
 21  MAGNETIC    AIR          SURFACE      MOBILE, CONTROLLED  SOLID(DISC.)   2-D SURFACE IMAGE
 22  MAGNETIC    AIR          UNDERWATER   MOBILE, CONTROLLED  SOLID(DISC.)   DETECT PRESENCE    (119) (21
2) (215)
 23  MAGNETIC    AIR          UNDERWATER   MOBILE, CONTROLLED  SOLID(DISC.)   MEASURE PROPERTIES (212) (21
5) (219)
 24  MAGNETIC    AIR          UNDERWATER   MOBILE, CONTROLLED  SOLID(DISC.)   2-D SURFACE IMAGE
 25  MAGNETIC    SURFACE      SURFACE      MOBILE, CONTROLLED  SOLID(DISC.)   DETECT PRESENCE    (212)
 26  MAGNETIC    SURFACE      SURFACE      MOBILE, CONTROLLED  SOLID(DISC.)   MEASURE PROPERTIES (212) (21
9)
 27  MAGNETIC    SURFACE      SURFACE      MOBILE, CONTROLLED  SOLID(DISC.)   2-D SURFACE IMAGE
 28  MAGNETIC    SURFACE      UNDERWATER   MOBILE, CONTROLLED  SOLID(DISC.)   DETECT PRESENCE    (212)
 29  MAGNETIC    SURFACE      UNDERWATER   MOBILE, CONTROLLED  SOLID(DISC.)   MEASURE PROPERTIES (212) (21
9)
 30  MAGNETIC    SURFACE      UNDERWATER   MOBILE, CONTROLLED  SOLID(DISC.)   2-D SURFACE IMAGE
 31  MAGNETIC    UNDERWATER   SURFACE      MOBILE, CONTROLLED  SOLID(DISC.)   DETECT PRESENCE    (212)
 32  MAGNETIC    UNDERWATER   SURFACE      MOBILE, CONTROLLED  SOLID(DISC.)   MEASURE PROPERTIES (212) (21
9)
 33  MAGNETIC    UNDERWATER   SURFACE      MOBILE, CONTROLLED  SOLID(DISC.)   2-D SURFACE IMAGE
 34  MAGNETIC    UNDERWATER   UNDERWATER   MOBILE, CONTROLLED  SOLID(DISC.)   DETECT PRESENCE    (212) (21
5)
 35  MAGNETIC    UNDERWATER   UNDERWATER   MOBILE, CONTROLLED  SOLID(DISC.)   MEASURE PROPERTIES (212) (21
5) (219)
 36  MAGNETIC    UNDERWATER   UNDERWATER   MOBILE, CONTROLLED  SOLID(DISC.)   2-D SURFACE IMAGE
 37  LIGHT       AIR          SURFACE      MOBILE, CONTROLLED  SOLID(DISC.)   DETECT PRESENCE    64   12
0  132  133  158  213  230 (231)
 38  LIGHT       AIR          SURFACE      MOBILE, CONTROLLED  SOLID(DISC.)   MEASURE PROPERTIES 132  13
3  202  230
 39  LIGHT       AIR          SURFACE      MOBILE, CONTROLLED  SOLID(DISC.)   2-D SURFACE IMAGE  64   94
   120  158  165  202  213  231
 40  LIGHT       AIR          UNDERWATER   MOBILE, CONTROLLED  SOLID(DISC.)   DETECT PRESENCE    (64) (89)
   (132)(133) (270) (273) (230) (267)
 41  LIGHT       AIR          UNDERWATER   MOBILE, CONTROLLED  SOLID(DISC.)   MEASURE PROPERTIES (132) (13
3) (230)
 42  LIGHT       AIR          UNDERWATER   MOBILE, CONTROLLED  SOLID(DISC.)   2-D SURFACE IMAGE  (64) (94)
   (267)
 43  LIGHT       SURFACE      SURFACE      MOBILE, CONTROLLED  SOLID(DISC.)   DETECT PRESENCE    132  13
3  158
 44  LIGHT       SURFACE      SURFACE      MOBILE, CONTROLLED  SOLID(DISC.)   MEASURE PROPERTIES 132  13
3
 45  LIGHT       SURFACE      SURFACE      MOBILE, CONTROLLED  SOLID(DISC.)   2-D SURFACE IMAGE  158
 46  LIGHT       SURFACE      UNDERWATER   MOBILE, CONTROLLED  SOLID(DISC.)   DETECT PRESENCE    132  13
3
 47  LIGHT       SURFACE      UNDERWATER   MOBILE, CONTROLLED  SOLID(DISC.)   MEASURE PROPERTIES 132  13
3
 48  LIGHT       SURFACE      UNDERWATER   MOBILE, CONTROLLED  SOLID(DISC.)   2-D SURFACE IMAGE
 49  LIGHT       UNDERWATER   SURFACE      MOBILE, CONTROLLED  SOLID(DISC.)   DETECT PRESENCE    132  13
3
 50  LIGHT       UNDERWATER   SURFACE      MOBILE, CONTROLLED  SOLID(DISC.)   MEASURE PROPERTIES 132  13
3
 51  LIGHT       UNDERWATER   SURFACE      MOBILE, CONTROLLED  SOLID(DISC.)   2-D SURFACE IMAGE  94
 52  LIGHT       UNDERWATER   UNDERWATER   MOBILE, CONTROLLED  SOLID(DISC.)   DETECT PRESENCE    76   13
2  (133) (273)  238  241
 53  LIGHT       UNDERWATER   UNDERWATER   MOBILE, CONTROLLED  SOLID(DISC.)   MEASURE PROPERTIES (132) (13
3)
 54  LIGHT       UNDERWATER   UNDERWATER   MOBILE, CONTROLLED  SOLID(DISC.)   2-D SURFACE IMAGE  (94)  11
4  122  170  (230)  238  241  1758
```

FIG. A.11. *(Cont.)*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 55 | MICROWAVES | AIR | SURFACE | MOBILE, CONTROLLED | SOLID(DISC.) | DETECT PRESENCE | 214 22 |
| 9 (231) 245 (260) | | | | | | | |
| 56 | MICROWAVES | AIR | SURFACE | MOBILE, CONTROLLED | SOLID(DISC.) | MEASURE PROPERTIES | 91 (92) |
| 192 | | | | | | | |
| 57 | MICROWAVES | AIR | SURFACE | MOBILE, CONTROLLED | SOLID(DISC.) | 2-D SURFACE IMAGE | 17 91 |
| 92 214 229 (231) 245 | | | | | | | |
| 58 | MICROWAVES | AIR | UNDERWATER | MOBILE, CONTROLLED | SOLID(DISC.) | DETECT PRESENCE | |
| 59 | MICROWAVES | AIR | UNDERWATER | MOBILE, CONTROLLED | SOLID(DISC.) | MEASURE PROPERTIES | |
| 60 | MICROWAVES | AIR | UNDERWATER | MOBILE, CONTROLLED | SOLID(DISC.) | 2-D SURFACE IMAGE | |
| 61 | MICROWAVES | SURFACE | SURFACE | MOBILE, CONTROLLED | SOLID(DISC.) | DETECT PRESENCE | |
| 62 | MICROWAVES | SURFACE | SURFACE | MOBILE, CONTROLLED | SOLID(DISC.) | MEASURE PROPERTIES | |
| 63 | MICROWAVES | SURFACE | SURFACE | MOBILE, CONTROLLED | SOLID(DISC.) | 2-D SURFACE IMAGE | |
| 64 | MICROWAVES | SURFACE | UNDERWATER | MOBILE, CONTROLLED | SOLID(DISC.) | DETECT PRESENCE | |
| 65 | MICROWAVES | SURFACE | UNDERWATER | MOBILE, CONTROLLED | SOLID(DISC.) | MEASURE PROPERTIES | |
| 66 | MICROWAVES | SURFACE | UNDERWATER | MOBILE, CONTROLLED | SOLID(DISC.) | 2-D SURFACE IMAGE | |
| 67 | MICROWAVES | UNDERWATER | SURFACE | MOBILE, CONTROLLED | SOLID(DISC.) | DETECT PRESENCE | |
| 68 | MICROWAVES | UNDERWATER | SURFACE | MOBILE, CONTROLLED | SOLID(DISC.) | MEASURE PROPERTIES | |
| 69 | MICROWAVES | UNDERWATER | SURFACE | MOBILE, CONTROLLED | SOLID(DISC.) | 2-D SURFACE IMAGE | |
| 70 | MICROWAVES | UNDERWATER | UNDERWATER | MOBILE, CONTROLLED | SOLID(DISC.) | DETECT PRESENCE | |
| 71 | MICROWAVES | UNDERWATER | UNDERWATER | MOBILE, CONTROLLED | SOLID(DISC.) | MEASURE PROPERTIES | |
| 72 | MICROWAVES | UNDERWATER | UNDERWATER | MOBILE, CONTROLLED | SOLID(DISC.) | 2-D SURFACE IMAGE | |

FIG. A.12. MORPHOLOGICAL ANALYSIS — HELICOPTER-AIDED ICE-BREAKING

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 1,3 | Helicopter detection and small-scale mapping of ice in low visibility | Spatial-scanning narrow-beam sound system. Radio link to vessel. | ** | | | | | ✓ | ✓ |
| | Use of tethered balloon platform in place of helicopter | Tethered communication link to vessel. | | | | | | | |
| 2 | Probably not practical to determine ice type with sound | | | | | | | | |
| 4-6 | Active sound device lowered from helicopter detects, maps, characterizes underwater portions of ice | Active sonar connected to helicopter. | ** | | | ✓ | ✓ | | ✓ |
| 8 | Small unmanned surface vehicle (snowmobile?) precedes vessel, guided by helicopter. Sound probe forced against ice measures thickness | Radio guidance link. Ultrasonic thickness measurement. | ** | | | | ✓ | ✓ | ✓ |
| 7,9 | Not relevant. (surface vehicle used only when ice present) | | | | | | | | |
| 10 | Probably impractical to probe underwater portions of ice from surface, except thickness as in 8 above | | | | 1 | | | | |
| 11,12 | As above | | | | | | | | |
| 13-15 | An underwater sensor detecting underwater portions of ice is considered in 16-18 below. | | | | | | | | |
| 16 | Underwater, unmanned, vehicle precedes vessel, controlled by it, detects ice | Narrow-beam scanning sonar. Untethered vehicle guidance. | 3 | 2 | 3 | ✓ | ✓ | | ✓ |
| 17 | As above, plus measure properties. | " " | ** | | 1 | | ✓ | | ✓ |
| 18 | As in 16, plus mapping over small area. | Narrow-beam scanning sonar. Side-scan sonars. Untethered vehicle guidance. | 4 | 2 | | ✓ | ✓ | | ✓ |
| 19,20 | Helicopter measurement of ice thickness, presence to determine vessel path. | Magnetic-eddy current device. Radio link to vessel. | 1 | | 2 | | ✓ | | ✓ |
| | Use of tethered balloon platform in place of helicopter | Tethered communication link to vessel. | | | | | | | |
| 21 | Detailed mapping probably not necessary. | | | | | | | | |
| 22-36 | Remaining "magnetic" scenerios do not appear relevant | | | | 4 | | | | |
| 37 | Observation of ice from helicopter by visible and IR means (thru ground fog) | Infrared detectors, spectral scanners. | 5 | 2 | 1 | ✓ | ✓ | | ✓ |
| 38 | Thickness determination from helicopter by IR | Infrared detectors | 3 | | 1 | ✓ | ✓ | | ✓ |
| 39 | Infrared imaging of small areas with ice from helicopter | " | 6 | | 2 | ✓ | ✓ | | ✓ |
| 37-39 | Use of tethered balloon platform in place of helicopter | Tethered communication link to vessel | | | | | | | |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

R - RELEVANT SENSORS FOUND, C - CLOSE TECHNOLOGY, N.R. - TECH. NOT REL., E - EXISTING TECH, OK, D - SPECIFIC DEVOPMENT REQ, N - NEW TECH REQ

FIG. A.12. MORPHOLOGICAL ANALYSIS — HELICOPTER-AIDED ICE-BREAKING

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 40 | Optical observation from the air of underwater portions of ice fields (except for | | | | 8 | | | | |
| 41 | thickness in 38 above) do not appear | | | | 3 | | | | |
| 42 | sensible | | | | 3 | | | | |
| 43 | Bow mounted sensor on ice breaker detects ice presence in low visibility | Infrared detectors, scanners | 3 | | | ✓ | | | ✓ |
| 44 | Thickness determination not practical from vessel | | | 2 | | | | | |
| 45 | As in 43, plus local mapping of ice | Infrared scanner | 1 | | | ✓ | | | ✓ |
| 46 | Optical observation from surface of underwater portions of | | | 2 | | | | | |
| 47 | ice fields does not appear feasible | | | 2 | | | | | |
| 48 | | | | | | | | | |
| 49 | Will consider underwater detection of ice optically in | | | 2 | | | | | |
| 50 | 52-54 below | | | 2 | | | | | |
| 51 | | | | 1 | | | | | |
| 52 | Underwater optical detection device from underwater guided vehicle in front of ice breaker | Laser radar. Telemetered information. Telemetering control of vehicle. | 3 | | 3 | ✓ | ✓ | | ✓ |
| 53 | Thickness determination underwater not feasible optically | (infrared not usable). | | | 2 | | | | |
| 54 | As in 52, plus mapping | | 3 | 2 | 2 | ✓ | ✓ | | ✓ |
| 55 | Microwave detection of ice from helicopter | Radar. Microwave radiometer. | 2 | 1 | 2 | ✓ | ✓ | | ✓ |
| 56 | As above, plus thickness determination | | 2 | | 1 | ✓ | ✓ | | ✓ |
| 57 | As in 55 plus mapping over small area | | 5 | 1 | 1 | ✓ | ✓ | | ✓ |
| 55-57 | Use of tethered balloon platform in place of helicopter | Tethered communication link to vessel. | | | | | | | |
| 58-60 | Not relevant or particularly feasible | | | | | | | | |
| 61 | Detection of ice by microwave surface sensor | Radar in icebreakers | ** | | | | | | |
| 62 | Thickness determination not practical from vessel, may be done from surface vehicle (as in 8), deployable sensor a possibility | Deployable, expendable probe similar to sonobuoy could be dropped to ice surface from helicopter, or rocket launched from icebreaker. | 0 | | | | | ✓ | ✓ |
| 63 | As in 61, plus local mapping | Radar on icebreaker. | ** | | | | | | |
| 64-66 | Microwave surface-to-underwater not relevant in icebreaking | | | | | | | | |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

R - RELEVANT SENSORS FOUND, C - CLOSE TECHNOLOGY, N.R. - TECH. NOT REL., E - EXISTING TECH, OK, D - SPECIFIC DEVOPMENT REQ, N - NEW TECH REQ

FIG. A.12. MORPHOLOGICAL ANALYSIS — HELICOPTER-AIDED ICE-BREAKING

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 67-69 | Microwave underwater — to-surface not relevant in ice-breaking | | | | | | | | |
| 70-72 | Microwave underwater — to-underwater not relevant in icebreaking | | | | | | | | |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

R - RELEVANT SENSORS FOUND, C - CLOSE TECHNOLOGY, N.R. - TECH. NOT REL., E - EXISTING TECH, OK, D - SPECIFIC DEVOPMENT REQ, N - NEW TECH REQ

# FIG. A.13. RESIDUAL MORPHOLOGY, PORT ANTI-SABOTAGE & TERRORISM

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SEARCH OVER THE FOLLOWING
RESIDUAL MORPHOLOGY. PORT ANTI-SABOTAGE& TERRORISM. 1/20/78

---SENSOR DESCRIPTORS---
5.1 FUNCTION
        .DETECTION
        .SURVEILLANCE

---ENVIRONMENT DESCRIPTORS---
6.2 AT OBJECT
        .SURFACE
        .UNDERWATER
        .BOTTOM
        .SUB-BOTTOM

---OBJECT DESCRIPTORS---
7.1 NATURE OF OBJECT SENSED
    DISCRETE OBJECT
        .ANIMATE(DISC.)
        .SOLID(DISC.)
7.3 OBJECT INFORMATION
    SYNOPTIC INFO.
        .DETECT PRESENCE
        .IDENTIFY FEATURES
    GEOMETRIC INFO.
        .2-D SURFACE IMAGE

    FUNCTION      ENV. AT OBJECT   OBJECT SENSED    OBJECT INFO.
 1  DETECTION     SURFACE          ANIMATE(DISC.)   DETECT PRESENCE    (27) 120 133 158 182 (207) 272 (231)
 2  DETECTION     SURFACE          ANIMATE(DISC.)   IDENTIFY FEATURES  120 158 (231)
 3  DETECTION     SURFACE          ANIMATE(DISC.)   2-D SURFACE IMAGE  120 158 (231)
 4  DETECTION     SURFACE          SOLID(DISC.)     DETECT PRESENCE    27 120 133 158 (200) (207) 212 214 220 27
2 (279) 229 231 (234) (236)(237) 245 260 (285)
 5  DETECTION     SURFACE          SOLID(DISC.)     IDENTIFY FEATURES  120 158 214 229 231 245
 6  DETECTION     SURFACE          SOLID(DISC.)     2-D SURFACE IMAGE  120 158 214 229 231 245
 7  DETECTION     UNDERWATER       ANIMATE(DISC.)   DETECT PRESENCE    11 24 25 26 27 66 (76) (87) (89) 10
1  116 (119) 128 (133) 142 174 (207) 209 210 (270) 272 (273) 274 275 276 278 255 (258) 261 263 264 265 266 (267)
 8  DETECTION     UNDERWATER       ANIMATE(DISC.)   IDENTIFY FEATURES  (101) 174 (209) (210) 275 (255)(258) 265 266
 9  DETECTION     UNDERWATER       ANIMATE(DISC.)   2-D SURFACE IMAGE  (101) 142 174 265 266 267
10  DETECTION     UNDERWATER       SOLID(DISC.)     DETECT PRESENCE    24 27 76 (87) 89 101 119 128 (133) 14
2  152 (153) (171) 174 (187A)(187B)(188) (189) 207 209 210 212 215 270 272 273 274 275 276 (277) 278 (223)(237) 251 255 258
 261 263 264 265 266 267 285
11  DETECTION     UNDERWATER       SOLID(DISC.)     IDENTIFY FEATURES  101 152 (171) 174 209 210 275 255 258 26
5  266
12  DETECTION     UNDERWATER       SOLID(DISC.)     2-D SURFACE IMAGE  (101) 142 152 (171) 174 265 266 267
13  DETECTION     BOTTOM           ANIMATE(DISC.)   DETECT PRESENCE    (27) 133 142 174
14  DETECTION     BOTTOM           ANIMATE(DISC.)   IDENTIFY FEATURES  174
15  DETECTION     BOTTOM           ANIMATE(DISC.)   2-D SURFACE IMAGE  142 174
16  DETECTION     BOTTOM           SOLID(DISC.)     DETECT PRESENCE    27 (86) (133) 142 151 152 (153) 171 174 21
2  215 (277) 268 (285)
17  DETECTION     BOTTOM           SOLID(DISC.)     IDENTIFY FEATURES  151 152 164 (171) 174
18  DETECTION     BOTTOM           SOLID(DISC.)     2-D SURFACE IMAGE  142 152 (171) 174
19  DETECTION     SUB-BOTTOM       ANIMATE(DISC.)   DETECT PRESENCE    (27)
20  DETECTION     SUB-BOTTOM       ANIMATE(DISC.)   IDENTIFY FEATURES
21  DETECTION     SUB-BOTTOM       ANIMATE(DISC.)   2-D SURFACE IMAGE
22  DETECTION     SUB-BOTTOM       SOLID(DISC.)     DETECT PRESENCE    27 42 28 212 215 268 (285)
23  DETECTION     SUB-BOTTOM       SOLID(DISC.)     IDENTIFY FEATURES
24  DETECTION     SUB-BOTTOM       SOLID(DISC.)     2-D SURFACE IMAGE
```

FIG. A.13. *(Cont.)*

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 25 SURVEILLANCE    SURFACE       ANIMATE(DISC.)  DETECT PRESENCE     64   75   120  158  182  205  213 (231)
 26 SURVEILLANCE    SURFACE       ANIMATE(DISC.)  IDENTIFY FEATURES   64   94   120  158 (205) 213 (231)
 27 SURVEILLANCE    SURFACE       ANIMATE(DISC.)  2-D SURFACE IMAGE   64   94   120  158  213 (231)
 28 SURVEILLANCE    SURFACE       SOLID(DISC.)    DETECT PRESENCE     64   93   120 (134) (137) 158  212  213  214  22
9 (230) 231  236  245
 29 SURVEILLANCE    SURFACE       SOLID(DISC.)    IDENTIFY FEATURES  (6)  (17)  64   94   120 (148A) 158  213  214 (22
9) 231  245
 30 SURVEILLANCE    SURFACE       SOLID(DISC.)    2-D SURFACE IMAGE  (5)  (6)  (17) (44)  64  (91) (93)  94   120 (14
8A) 158 (165) 213  214 (229) 231  245
 31 SURVEILLANCE    UNDERWATER    ANIMATE(DISC.)  DETECT PRESENCE     29  (36)  52  (64)  66  (87)  89   101 (119) 12
8  209  210 (274) 275 (278) 238 (255) 258 (261) 264  266
 32 SURVEILLANCE    UNDERWATER    ANIMATE(DISC.)  IDENTIFY FEATURES   23  (64)  83   101 (94)  113  114  122 (209)(21
0) 275 (232) 233  238  255  258  266  175B
 33 SURVEILLANCE  . UNDERWATER    ANIMATE(DISC.)  2-D SURFACE IMAGE   23  (34) (64)  101 (94)  113  114  122  170 (23
2) 233  238  266  175B
 34 SURVEILLANCE    UNDERWATER    SOLID(DISC.)    DETECT PRESENCE     29  (64) (87)  89   101  119  128  152  175A 20
9  210  212  215  274  275  278 (230) 238  251  252  255  258  261  264  266
 35 SURVEILLANCE    UNDERWATER    SOLID(DISC.)    IDENTIFY FEATURES   23  (64)  83   88   101  94   113  114  122  12
5  152 (209)(210) 271 (275)(232) 233  238 (255)(258) 266  175D
 36 SURVEILLANCE    UNDERWATER    SOLID(DISC.)    2-D SURFACE IMAGE   23  (34) (64) (101) 94   113  114  122  152  17
0  175A 232  233  238  266  175B
 37 SURVEILLANCE    BOTTOM        ANIMATE(DISC.)  DETECT PRESENCE
 38 SURVEILLANCE    BOTTOM        ANIMATE(DISC.)  IDENTIFY FEATURES   114  232  233  175B
 39 SURVEILLANCE    BOTTOM        ANIMATE(DISC.)  2-D SURFACE IMAGE   114  232  233  175B
 40 SURVEILLANCE    BOTTOM        SOLID(DISC.)    DETECT PRESENCE     51   86   151  152  175A 212  215 (230) 252
 41 SURVEILLANCE    BOTTOM        SOLID(DISC.)    IDENTIFY FEATURES   51   80   114  151  152  164 (232) 233  175B
 42 SURVEILLANCE    BOTTOM        SOLID(DISC.)    2-D SURFACE IMAGE   80   114  152  175A (232) 233  175B
 43 SURVEILLANCE    SUB-BOTTOM    ANIMATE(DISC.)  DETECT PRESENCE
 44 SURVEILLANCE    SUB-BOTTOM    ANIMATE(DISC.)  IDENTIFY FEATURES
 45 SURVEILLANCE    SUB-BOTTOM    ANIMATE(DISC.)  2-D SURFACE IMAGE
 46 SURVEILLANCE    SUB-BOTTOM    SOLID(DISC.)    DETECT PRESENCE     212  215
 47 SURVEILLANCE    SUB-BOTTOM    SOLID(DISC.)    IDENTIFY FEATURES
 48 SURVEILLANCE    SUB-BOTTOM    SOLID(DISC.)    2-D SURFACE IMAGE
```

FIG. A.14. MORPHOLOGICAL ANALYSIS — PORT ANTI-SABOTAGE AND TERRORISM

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 1 | Detection of swimmers on surface | Visual, IR optical sensors, high resolution radar | 4 | 1 | 3 | ✓ | | | |
| 2-3 | Identify and obtain image of surface swimmers | Visual, IR optical sensors, TV imaging | 2 | | 1 | ✓ | | | |
| 4 | Detect surface vessels and small craft | Visual and IR sensors, high resolution radar, magnetic loops, acoustic sensors | 7 | 5 | 7 | ✓ | | | |
| 5-6 | Identify and obtain image of surface craft | Visual and IR imaging, high resolution radar | 3 | 3 | | ✓ | | | |
| 7 | Detect underwater swimmers | Active doppler sonar, passive acoustic sensors, optical (clear water) | 17 | 7 | 10 | ✓ | | | |
| 8 | Identify underwater targets as swimmers | Active doppler sonar, bistatic high-resolution sonar | 2 | 2 | 5 | ✓ | ✓ | | ✓ |
| 9 | Obtain 2-D image of underwater swimmers | Active high-resolution sonar imaging, underwater TV (clear water) | 5 | | 1 | ✓ | | | |
| 10 | Detect submersible, underwater ordinance, or underwater device | Active high-resolution sonar, LIDAR (in clear water) MAD equipment | 26 | 5 | 11 | ✓ | | | |
| 11 | Identify underwater targets as potential threats | Active high-resolution sonar | 7 | 3 | 1 | ✓ | | | |
| 12 | Obtain 2-D image of underwater targets | Sonar imaging, underwater TV (clear water) | 6 | | 2 | ✓ | | | |
| 13 | Detect swimmers (divers) on bottom | Active high-resolution sonar | 2 | | 2 | ✓ | | | |
| 14 | Identify objects near or on bottom as swimmers | Active doppler sonar | | 1 | | ✓ | ✓ | | ✓ |
| 15 | Obtain 2-D image of swimmers (divers on bottom) | High-resolution imaging sonar, underwater TV (clear water) | 2 | | | ✓ | | | |
| 16 | Detection of submersible, ordinance or objects on bottom | High-resolution sonar, side scan sonar, MAD gear | 9 | | 5 | ✓ | | | |
| 17-18 | Identify and obtain image of bottom objects | Side-scan sonar, high-resolution imaging sonar, underwater TV (clear water) | 5 | | 1 | ✓ | | | |
| 19 | Detect diver tunneling in bottom | Not practical, but sub-bottom profiling equipment appropriate (key 28, 147) | 2* | | 1 | ✓ | | | |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

R - RELEVANT SENSORS FOUND, C - CLOSE TECHNOLOGY, N.R. - TECH. NOT REL., E - EXISTING TECH, OK, D - SPECIFIC DEVOPMENT REQ., N - NEW TECH REQ.

FIG. A.14. MORPHOLOGICAL ANALYSIS — PORT ANTI-SABOTAGE AND TERRORISM

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 20-21 | Not practical | | 0 | | | | | | |
| 22 | Detect presence of objects buried in bottom | Mine detection sonar, deep towed magnetometers | 6 | | 1 | ✓ | | | |
| 23-24 | Not practical | | 0 | | | | | | |
| 25 | Surveillance of surface for swimmers | IR and visible light sensors, high resolution radar | 4 | 3 | 1 | ✓ | | | |
| 26-27 | Identify and obtain image of surface swimmers (installed sensors) | IR and visible light imaging | 5 | | 2 | ✓ | | | |
| 28 | Surveillance of surface for surface vessels, small craft, objects | Radar, IR and visible light sensors | 7 | 4 | 3 | ✓ | | | |
| 29-30 | Identify and obtain image of surface vessels, small craft, objects (installed sensors) | High resolution radar, passive microwave imaging. synth-aperture radar | 10 | 3 | 4 | ✓ | | | |
| 31 | Surveillance for underwater swimmers | High resolution sonar, doppler sonar, optical sensors (clear water) | 5 | 7 | 8 | ✓ | | | |
| 32-33 | Identify and obtain image of underwater swimmers (installed sensors) | As above and active acoustic barrier system along bottom — similar to fish counters | 10 | 5 | 5 | ✓ | ✓ | | ✓ |
| 34 | Surveillance to detect underwater objects - submersibles | Active, high-resolution sonar, magnetometers, optical sensor (clear water) | 12 | 10 | 3 | ✓ | | | |
| 35-36 | Identify and obtain image of underwater objects (installed sensors) | High-resolution, imaging sonars, underwater TV (clear water) | 14 | 4 | 7 | ✓ | | | |
| 37 | Surveillance to detect a swimmer on the bottom | Barrier type active doppler sonar ("fish counter" principle) | 0 | | | | ✓ | | ✓ |
| 38-39 | Identify and obtain image of swimmer on bottom (installed sensors) | High-resolution imaging sonars, underwater TV (clear water) | 3 | 1 | | ✓ | | | |
| 40 | Surveillance to detect a submersible of suspicious objects on bottom | Side-scan sonar, barrier type sonars, magnetic detection loops | 7 | 1 | 1 | ✓ | ✓ | | ✓ |
| | | | | | | | | | |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

R - RELEVANT SENSORS FOUND, C - CLOSE TECHNOLOGY, N.R. - TECH. NOT REL., E - EXISTING TECH, OK, D - SPECIFIC DEVOPMENT REQ, N - NEW TECH REQ

FIG. A.14. MORPHOLOGICAL ANALYSIS — PORT ANTI-SABOTAGE AND TERRORISM

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 41-42 | Identify and obtain image of submersible or other objects on bottom (installed sensors) | Side-scan sonar, underwater TV (clear water) high-resolution imaging sonars | 8 | 1 | 1 | ✓ | | | |
| 43-45 | Not practical | | 0 | | | | | | |
| 46 | Surveillance to detect buried mines and other objects | MAD systems, bottom penetrating sonar | 2 | | | ✓ | | | |
| 47-48 | Identify and obtain image of buried objects (installed sensors) | Not feasible for installed equipment, periodic survey with mine detecting sonar and magnetometers more practical | 0 | | | | | | |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

R - RELEVANT SENSORS FOUND, C - CLOSE TECHNOLOGY, N.R. - TECH. NOT REL., E - EXISTING TECH, OK, D - SPECIFIC DEVOPMENT REQ., N - NEW TECH REQ

## FIG. A.15. RESIDUAL MORPHOLOGY, AIDS TO NAVIGATION

SEARCH OVER THE FOLLOWING

---SENSOR DESCRIPTORS---
5.4 STIMULUS USED
  ACOUSTIC
    .H.F. SOUND
  FORCE FIELD
    .MAGNETIC
  ELECTROMAGNETIC
    .RADIO WAVES

---ENVIRONMENT DESCRIPTORS---
6.1 AT SENSOR
    .SURFACE
    .UNDERWATER
6.2 AT OBJECT
    .SURFACE
    .UNDERWATER
    .BOTTOM
6.3 SENSOR PLATFORM
    .MOBILE, CONTROLLED
6.4 SENSOR OBJECT PROXIMITY
    .REMOTE

---OBJECT DESCRIPTORS---
7.1 NATURE OF OBJECT SENSED
  DISCRETE OBJECT
    .SOLID(DISC.)
7.2 OBJECT-STIMULUS INTERACTION
  ACTIVE OBJECT
    .COOPERATIVE EMISS.
    .STIMULATED EMISS.
    .SPONTANEOUS EMISS.
  PASSIVE OBJECT
    .REFLECTION

| | STIMULUS USED | ENV. AT SENSOR | ENV. AT OBJECT | SENSOR PLATFORM | PROXIMITY | OBJECT SENSED | INTERACTION |
|---|---|---|---|---|---|---|---|
| 1 | H.F. SOUND | SURFACE | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COOPERATIVE EMISS. |
| 2 | H.F. SOUND | SURFACE | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | STIMULATED EMISS. |
| 3 | H.F. SOUND | SURFACE | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SPONTANEOUS EMISS. |
| 4 | H.F. SOUND | SURFACE | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | REFLECTION |
| 5 | H.F. SOUND | SURFACE | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COOPERATIVE EMISS. 188 |
| 6 | H.F. SOUND | SURFACE | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | STIMULATED EMISS. |
| 7 | H.F. SOUND | SURFACE | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SPONTANEOUS EMISS. |
| 8 | H.F. SOUND | SURFACE | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | REFLECTION |
| 9 | H.F. SOUND | SURFACE | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COOPERATIVE EMISS. |
| 10 | H.F. SOUND | SURFACE | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | STIMULATED EMISS. |

FIG. A.15 *(Cont.)*

| | | | | | | |
|---|---|---|---|---|---|---|
| 11 H.F. SOUND<br>NEOUS EMISS. | SURFACE | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SPONTA |
| 12 H.F. SOUND<br>TION | SURFACE | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | REFLEC |
| 13 H.F. SOUND<br>ATIVE EMISS. | UNDERWATER | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COOPER |
| 14 H.F. SOUND<br>ATED EMISS. | UNDERWATER | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | STIMUL |
| 15 H.F. SOUND<br>NEOUS EMISS. | UNDERWATER | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SPONTA |
| 16 H.F. SOUND<br>TION | UNDERWATER | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | REFLEC |
| 17 H.F. SOUND<br>ATIVE EMISS. 2 34 58 153 189 208 277 | UNDERWATER | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COOPER |
| 18 H.F. SOUND<br>ATED EMISS. 175A | UNDERWATER | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | STIMUL |
| 19 H.F. SOUND<br>NEOUS EMISS. 208 | UNDERWATER | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SPONTA |
| 20 H.F. SOUND<br>TION (88) 101 140 (142) 152 173 174 175A | UNDERWATER | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | REFLEC |
| 21 H.F. SOUND<br>ATIVE EMISS. 143 153 277 | UNDERWATER | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COOPER |
| 22 H.F. SOUND<br>ATED EMISS. 175A | UNDERWATER | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | STIMUL |
| 23 H.F. SOUND<br>NEOUS EMISS. | UNDERWATER | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SPONTA |
| 24 H.F. SOUND<br>TION 31 49 139 (140) (142) 151 152 154 164 173 174 175A 176 208 | UNDERWATER | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | REFLEC |
| 25 MAGNETIC<br>ATIVE EMISS. | SURFACE | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COOPER |
| 26 MAGNETIC<br>ATED EMISS. | SURFACE | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | STIMUL |
| 27 MAGNETIC<br>NEOUS EMISS. 212 | SURFACE | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SPONTA |
| 28 MAGNETIC<br>TION | SURFACE | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | REFLEC |
| 29 MAGNETIC<br>ATIVE EMISS. | SURFACE | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COOPER |
| 30 MAGNETIC<br>ATED EMISS. | SURFACE | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | STIMUL |
| 31 MAGNETIC<br>NEOUS EMISS. 212 | SURFACE | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SPONTA |
| 32 MAGNETIC<br>TION | SURFACE | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | REFLEC |
| 33 MAGNETIC<br>ATIVE EMISS. | SURFACE | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COOPER |
| 34 MAGNETIC<br>ATED EMISS. | SURFACE | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | STIMUL |
| 35 MAGNETIC<br>NEOUS EMISS. 177 (212) | SURFACE | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SPONTA |
| 36 MAGNETIC<br>TION | SURFACE | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | REFLEC |
| 37 MAGNETIC<br>ATIVE EMISS. | UNDERWATER | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COOPER |
| 38 MAGNETIC<br>ATED EMISS. | UNDERWATER | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | STIMUL |
| 39 MAGNETIC<br>NEOUS EMISS. 212 | UNDERWATER | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SPONTA |
| 40 MAGNETIC<br>TION | UNDERWATER | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | REFLEC |

FIG. A.15. *(Cont.)*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 41 | MAGNETIC<br>ATIVE EMISS. | UNDERWATER | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COOPER |
| 42 | MAGNETIC<br>ATED EMISS. | UNDERWATER | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | STIMUL |
| 43 | MAGNETIC<br>NEOUS EMISS. 212 215 | UNDERWATER | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SPONTA |
| 44 | MAGNETIC<br>TION | UNDERWATER | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | REFLEC |
| 45 | MAGNETIC<br>ATIVE EMISS. | UNDERWATER | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COOPER |
| 46 | MAGNETIC<br>ATED EMISS. | UNDERWATER | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | STIMUL |
| 47 | MAGNETIC<br>NEOUS EMISS. 177 212 215 | UNDERWATER | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SPONTA |
| 48 | MAGNETIC<br>TION | UNDERWATER | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | REFLEC |
| 49 | RADIO WAVES<br>ATIVE EMISS. 249 | SURFACE | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COOPER |
| 50 | RADIO WAVES<br>ATED EMISS. | SURFACE | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | STIMUL |
| 51 | RADIO WAVES<br>NEOUS EMISS. | SURFACE | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SPONTA |
| 52 | RADIO WAVES<br>TION | SURFACE | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | REFLEC |
| 53 | RADIO WAVES<br>ATIVE EMISS. | SURFACE | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COOPER |
| 54 | RADIO WAVES<br>ATED EMISS. | SURFACE | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | STIMUL |
| 55 | RADIO WAVES<br>NEOUS EMISS. | SURFACE | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SPONTA |
| 56 | RADIO WAVES<br>TION | SURFACE | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | REFLEC |
| 57 | RADIO WAVES<br>ATIVE EMISS. | SURFACE | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COOPER |
| 58 | RADIO WAVES<br>ATED EMISS. | SURFACE | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | STIMUL |
| 59 | RADIO WAVES<br>NEOUS EMISS. | SURFACE | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SPONTA |
| 60 | RADIO WAVES<br>TION | SURFACE | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | REFLEC |
| 61 | RADIO WAVES<br>ATIVE EMISS. 108 | UNDERWATER | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COOPER |
| 62 | RADIO WAVES<br>ATED EMISS. | UNDERWATER | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | STIMUL |
| 63 | RADIO WAVES<br>NEOUS EMISS. 78 | UNDERWATER | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SPONTA |
| 64 | RADIO WAVES<br>TION | UNDERWATER | SURFACE | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | REFLEC |
| 65 | RADIO WAVES<br>ATIVE EMISS. | UNDERWATER | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COOPER |
| 66 | RADIO WAVES<br>ATED EMISS. | UNDERWATER | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | STIMUL |
| 67 | RADIO WAVES<br>NEOUS EMISS. | UNDERWATER | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SPONTA |
| 68 | RADIO WAVES<br>TION | UNDERWATER | UNDERWATER | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | REFLEC |
| 69 | RADIO WAVES<br>ATIVE EMISS. | UNDERWATER | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | COOPER |
| 70 | RADIO WAVES<br>ATED EMISS. | UNDERWATER | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | STIMUL |
| 71 | RADIO WAVES<br>NEOUS EMISS. 106 | UNDERWATER | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | SPONTA |
| 72 | RADIO WAVES<br>TION | UNDERWATER | BOTTOM | MOBILE, CONTROLLED | REMOTE | SOLID(DISC.) | REFLEC |

FIG. A.16. MORPHOLOGICAL ANALYSIS — AIDS TO NAVIGATION

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV RECOM |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 1 | Surface navaids with acoustic signals (cooperative) | Bell, whistle, horn signals | 0** | | | ✓ | | | |
| 2 | Surface navaids with stimulated acoustic signal | Not practical | 0 | | | | | | |
| 3 | Surface navaids with spontaneous (continuous) acoustic signal | Not practical | 0 | | | | | | |
| 4 | Surface navaids reflecting acoustic signals | Not practical | 0 | | | | | | |
| 5 | Underwater acoustic navaids, receiver on surface | Not feasible | 1* | | | | | | |
| 6-12 | As above | As above | 0 | | | | | | |
| 13-16 | Underwater receiver for surface acoustic navaid | Not practical | 0 | | | | | | |
| 17 | Underwater acoustic navaid, underwater receiver | Pingers, transponders, directional hydrophones | 4 | 3 | | ✓ | | | |
| 18 | Underwater acoustic navaid, stimulated emission | Transponders generating an artificial ping echo | 1* | | | ✓ | | | |
| 19 | Underwater acoustic navaid, spontaneous (continuous) emission | Not practical (needs too much power) | 1 | | | ✓ | | | |
| 20 | Underwater acoustic navaid, reflector | Tuned or corner reflectors for sonar-aided navigation | 1 | 5 | 2 | ✓ | | | |
| 21 | Underwater acoustic navaid on bottom, underwater receiver | Acoustic beacons for ice-covered areas, locator beacons or transponders for marking surface navaid position to assist in repositioning aid | 3 | | | ✓ | ✓ | | ✓ |
| 22 | Acoustic navaid on bottom, stimulated emission | Transponder with artificial ping echo | | 1 | | ✓ | | | |
| 23 | Acoustic navaid on bottom, spontaneous (continuous) emission | Not practical | 0 | | | ✓ | | | |
| 24 | Acoustic navaid on bottom, reflector | Tuned reflectors or corner reflectors for bottom reference point markers. Useful for repositioning navaid anchors | 6 | 6 | 2 | ✓ | ✓- | | ✓ |
| 25-28 | Surface navaid producing magnetic field anomaly, sensed on surface | Not practical | 1 | | | ✓ | | | |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

R - RELEVANT SENSORS FOUND, C - CLOSE TECHNOLOGY, N.R. - TECH. NOT REL., E - EXISTING TECH, OK, D - SPECIFIC DEVOPMENT REQ, N - NEW TECH REQ

FIG. A.16. MORPHOLOGICAL ANALYSIS — AIDS TO NAVIGATION

| REF. LINE NR. | IMPLIED SCENARIO(S) FROM MORPHOLOGY COMBINATION ON REF. LINE | APPROPRIATE SENSOR SYSTEM(S) OR COMMENTS ON MORPHOLOGICAL COMBINATION | DATA BASE SENSORS | | | INDICATED TECH | | | USCG DEV. RECOM. |
|---|---|---|---|---|---|---|---|---|---|
| | | | R | C | NR | E | D | N | |
| 29-32 | Underwater navaid producing magnetic field anomaly, sensed on surface | Not practical | 1 | | | ✓ | | | |
| 33 | Navaid producing magnetic field on bottom, sensor on surface | Cables on bottom could provide pulsed magnetic field for position indication to surface vessels | 0 | | | ✓ | ✓ | | |
| 34-36 | As above, stimulated, spontaneous or reflected magnetic field | Not practical | 1 | | 1 | ✓ | | | |
| 37-40 | Navaid producing magnetic field on surface, sensor underwater | Not practical | 1 | | | ✓ | | | |
| 41-44 | Navaid producing magnetic field underwater, sensor underwater | Not practical | 2 | | | ✓ | | | |
| 45-48 | Navaid producing magnetic field on bottom, sensor underwater | Cables on bottom providing magnetic guideway for submersible navigation | 2 | 1 | | ✓ | ✓ | | |
| 49-52 | Surface radio navaids, surface receivers | LORAN, DECCA, OMEGA and other electronic aids | 0** | | | ✓ | | | |
| 53-56 | Underwater radio navaids, surface receivers | Not practical | 0 | | | | | | |
| 57-60 | Radio navaids on bottom, surface receivers | Not practical | 0 | | | | | | |
| 61-64 | Radio navaids on surface, underwater receivers | OMEGA for shallow receivers and strong signals | 2 | | | ✓ | | | |
| 65-68 | Radio navaids underwater, underwater receivers | Not practical | 0 | | | | | | |
| 69-72 | Radio navaids on bottom, underwater receivers | May be useful as a submersible navaid system for specialized work on rough ocean bottom. This would not have problems with multipath propagation and shadowing. ELF signals only. | 0 | | | | | ✓ | ✓ |

CODE SYMBOLS: *DATA BASE TAXONOMY REVISION NEEDED
**DATA BASE ADDITION NEEDED

R - RELEVANT SENSORS FOUND, C - CLOSE TECHNOLOGY, N.R. - TECH. NOT REL., E - EXISTING TECH, OK, D - SPECIFIC DEVOPMENT REQ, N - NEW TECH REQ

## APPENDIX B – INSTRUCTIONS FOR TEMPLATE AND RESIDUAL PROGRAMS AND SUMMARY OF SENSOR SYSTEM DATA BASE

Section 1 of this appendix contains a set of instructions for the TEMPLATE and RESIDUAL programs used to search the sensor data base developed in this study. An annotated listing of these programs, written in Wang Basic, has been supplied separately. A "Diskette" with the programs and a complete short-form sensor list has also been supplied for use with the Wang Model 2200 Computer Systems installed in Coast Guard facilities.

Section 2 consists of a complete short form list of all the sensor systems in the data base. Each sensor entry contains the key number, the title or system description, and its specific use. For a more complete description of a specific system, please refer to Appendix C (Unclassified Sensor Systems) or Appendix D (Classified Sensor Systems). These appendices are separately bound.

### B.1 Instruction for "TEMPLATE" and "RESIDUAL" Programs for Sensor Information Search

The program to sort through sensor data is stored on a floppy disk. The program name is TEMPLATE. The following description explains how to load and run the program. A discussion of the conventions used is included.

## GETTING ON THE COMPUTER

First turn on the computer. Make sure the floppy disk unit and the printer also are turned on. The screen should show

READY
:

Place the floppy disk containing the program into the floppy disk drive marked B10 (the second from the left) and shut the door. Be careful that the ↑UP on the diskette actually does point up.

Now type:

:LOAD DC R "TEMPLATE" (return)

at the keyboard. The GOTHIC letters indicate user type-in and (return) means the return key. The program now will be read in from the floppy disk. A colon will appear when it has finished loading.

## CONVENTIONS

Let's pause to cover the conventions used in this program. In general a question may be answered with an appropriate name or value or with one of the following: HELP, EXIT, XXX, DONE, or NONE.

## HELP

Typing HELP will cause the computer to print out the possible options in response to the question. The program then repeats the question.

EXIT

Typing EXIT causes the computer to assume that the user wishes to abort from the present level of the program to a higher level. At the highest level, it causes the program to finish. All values within the program remain at their last values.

It is possible to stop the program at any time by pressing the HALT/STEP key. Values which have been input are still in the machine and the program may be continued by pressing the CONTINUE key.

XXX

XXX may be used by itself or at the end of a type-in if the user feels he wants to repeat the question. The program ignores what has been typed in and tries again.

DONE

DONE is typed when the user has finished with the present level of the program and he wants to go on to the next level.

NONE

Typing NONE re-initializes the present level of the program.

RUN PROCEDURE

A blank template form is included on the following page for use in entering information for specific searches.

The program is started by typing

:RUN (return)

SENSOR TITLE OR REF. NO.________________

## 5. SENSOR DESCRIPTORS

### 5.1 Function (circle all appropriate)

1 Navigation  
2 Detection  
3 Surveillance (monitoring)  
4 Parametric Measurement  
5 Information Transfer

### 5.1.1 Specific use

________________  
(short description)

### 5.2 Sensing Method (Circle 1)

1 Direct  
2 Indirect

(If indirect, show which of descriptors apply to the direct (D) and to the indirect (I) stimuli)

### 5.3 Sensor Involvement (Circle 1)

1 Active  2 Passive

### 5.4 Stimulus Used (circle all appropriate)

| 1 Mechanical | 2 Acoustic | 3 Force Field |
|---|---|---|
| 1 Fluid Motion | 1 Vibration | 1 Gravitation |
| 2 Lin. or Rd. Motion | 2 L.F. Sound | 2 Magnetic |
| 3 Nuclear Particles | 3 M.F. Sound | 3 Electrostatic |
| 4 Heat | 4 H.F. Sound | 4 Electromotive |
| 5 Pressure | | |

| 4 Electromagnetic | 5 Chemical |
|---|---|
| 1 Ionizing waves | 1 Molecular bond |
| 2 Light | 2 Electrochemical |
| 3 Microwaves | 3 Thermochemical |
| 4 Radio waves | |

### 5.5 Stimulus Property Sensed (circle all appropriate)

| Scalar | Vector | Time-Frequency |
|---|---|---|
| 1 off-on | 1 direction | 1 time-interval |
| 2 amplitude | 2 force | 2 period |
| 3 temperature | 3 displacement | 3 frequency |
| 4 volume | 4 velocity | 4 spectrum |
| 5 voltage/ current | 5 acceleration | 5 color |
| 6 chemical change | 6 polarization | |

### 5.6 Sensor Availability (Circle 1)

1 Commercial Product  
2 Laboratory Prototype  
3 Development Project (available within 3 years)  
4 Theoretical Study (availability not known)

## 6. ENVIRONMENT DESCRIPTORS

### 6.1 At Sensor (circle all appropriate)

1 Space  
2 Air  
3 Surface  
4 Underwater  
5 Bottom  
6 Sub-bottom

### 6.2 At Object (circle all appropriate)

1 Space  
2 Air  
3 Surface  
4 Underwater  
5 Bottom  
6 Sub-bottom

### 6.3 Sensor Platform (circle all appropriate)

1 Fixed  
2 Mobile, controlled  
3 Mobile, free  
4 Free fall  
5 Hand held  
6 Tethered

### 6.4 Sensor Object Proximity

1 Contact  
2 Near  
3 Remote

## 7. OBJECT DESCRIPTORS

### 7.1 Nature of Object(s) Sensed (circle all appropriate)

| 1 Discrete Object (or medium boundary) | 2 Distributed Objects (within medium) | Continuous Medium |
|---|---|---|
| 1 Animate (mobile) | 1 Animate (mobile) | 1 Solid |
| 2 Solid | 2 Particles | 2 Liquid |
| 3 Gelatinous | 3 Droplets | 3 Gas |
| 4 Liquid | 4 Bubbles | |
| 5 Film | | |
| 6 Gas | | |

### 7.2 Object-Stimulus Interaction (circle all appropriate)

| 1 Active Object | 2 Passive Object |
|---|---|
| 1 Cooperative Emission | 1 Reflection |
| 2 Stimulated Emission | 2 Refraction |
| 3 Spontaneous Emission | 3 Scattering |
| | 4 Absorption |
| | 5 Field Perturbation |
| | 6 Indirect |

### 7.3 Object Information (circle all appropriate)

| 1 Information Transfer | 2 Synoptic Information | 3 Geometric Information |
|---|---|---|
| 1 Communication | 1 Detect Presence | 1 Volumetric |
| 2 Data Telemetry | 2 Identify Features | 2 2-D Image of Surface |
| 3 System Control | 3 Measure Properties | 3 3-D Image of Surface |
| | 4 Determine Motion or Change of Form | 4 3-D Image plus Interior Details |

It will now ask the user several set-up questions.

## Output Destination

All output from the program appears on the CRT. If printer output also is desired, answer this question with P.

## Output Format

There are two choices, long or short. Long form gives all stored information about each sensor. The short form gives the key number, the specific use and the sensor title only.

## Search Type

Searches may be performed in "regular" or "or" mode. In "regular" mode each item in the template must be matched by the record before it is printed. In "or" mode, any match in a category makes the record acceptable.

## Skipping Records

The entire data base need not be searched. The records to be covered are specified by saying ALL or by giving the first and last to be searched. (The numbers given refer to position in the data base and not to key numbers.)

## Making the Template

When the set-up is finished the user is ready to build a template of the items he wants to match. The number of options on the highest level is limited because not all possibilities were put into the program. It is possible to include sensor, environment, object and key, but all other descriptors are ignored in the template. As an example, let's construct a template which will include the following:

(SEE EXAMPLE TEMPLATE)

# EXAMPLE TEMPLATE

SENSOR TITLE OR REF. NO. Example

5. SENSOR DESCRIPTORS

5.1 Function (circle all appropriate)

| | |
|---|---|
| 1 Navigation | 4 Parametric Measurement |
| 2 Detection | 5 Information Transfer |
| 3 Surveillance (monitoring) | |

5.1.1 Specific use

(short description)

5.2 Sensing Method (Circle 1)

1 Direct
2 Indirect

(If indirect, show which of descriptors apply to the direct (D) and to the indirect (I) stimuli)

5.3 Sensor Involvement (Circle 1)

1 Active  2 Passive

5.4 Stimulus Used (circle all appropriate)

| 1 Mechanical | 2 Acoustic | 3 Force Field |
|---|---|---|
| 1 Fluid Motion | 1 Vibration | 1 Gravitation |
| 2 Lin. or Rd. Motion | 2 L.F. Sound | 2 Magnetic |
| 3 Nuclear Particles | 3 M.F. Sound | 3 Electrostatic |
| 4 Heat | 4 H.F. Sound | 4 Electromotive |
| 5 Pressure | | |

| 4 Electromagnetic | 5 Chemical |
|---|---|
| 1 Ionizing waves | 1 Molecular bond |
| 2 Light | 2 Electrochemical |
| 3 Microwaves | 3 Thermochemical |
| 4 Radio waves | |

5.5 Stimulus Property Sensed (circle all appropriate)

| Scalar | Vector | Time-Frequency |
|---|---|---|
| 1 off-on | 1 direction | 1 time-interval |
| 2 amplitude | 2 force | 2 period |
| 3 temperature | 3 displacement | 3 frequency |
| 4 volume | 4 velocity | 4 spectrum |
| 5 voltage/ current | 5 acceleration | 5 color |
| 6 chemical change | 6 polarization | |

5.6 Sensor Availability (Circle 1)

1 Commercial Product
2 Laboratory Prototype
3 Development Project (available within 3 years)
4 Theoretical Study (availability not known)

6. ENVIRONMENT DESCRIPTORS

6.1 At Sensor (circle all appropriate)

| | |
|---|---|
| 1 Space | 4 Underwater |
| 2 Air | 5 Bottom |
| 3 Surface | 6 Sub-bottom |

6.2 At Object (circle all appropriate)

| | |
|---|---|
| 1 Space | 4 Underwater |
| 2 Air | 5 Bottom |
| 3 Surface | 6 Sub-bottom |

6.3 Sensor Platform (circle all appropriate)

| | |
|---|---|
| 1 Fixed | 4 Free fall |
| 2 Mobile, controlled | 5 Hand held |
| 3 Mobile, free | 6 Tethered |

6.4 Sensor Object Proximity

1 Contact
2 Near
3 Remote

7. OBJECT DESCRIPTORS

7.1 Nature of Object(s) Sensed (circle all appropriate)

| 1 Discrete Object (or medium boundary) | 2 Distributed Objects (within medium) | Continuous Medium |
|---|---|---|
| 1 Animate (mobile) | 1 Animate (mobile) | 1 Solid |
| 2 Solid | 2 Particles | 2 Liquid |
| 3 Gelatinous | 3 Droplets | 3 Gas |
| 4 Liquid | 4 Bubbles | |
| 5 Film | | |
| 6 Gas | | |

7.2 Object-Stimulus Interaction (circle all appropriate)

| 1 Active Object | 2 Passive Object |
|---|---|
| 1 Cooperative Emission | 1 Reflection |
| 2 Stimulated Emission | 2 Refraction |
| 3 Spontaneous Emission | 3 Scattering |
| | 4 Absorption |
| | 5 Field Perturbation |
| | 6 Indirect |

7.3 Object Information (circle all appropriate)

| 1 Information Transfer | 2 Synoptic Information | 3 Geometric Information |
|---|---|---|
| 1 Communication | 1 Detect Presence | 1 Volumetric |
| 2 Data Telemetry | 2 Identify Features | 2 2-D Image of Surface |
| 3 System Control | 3 Measure Properties | 3 3-D Image of Surface |
| | 4 Determine Motion or Change of Form | 4 3-D Image plus Interior Details |

Navigation under Sensor function, Underwater for sensor and object under Environment, and Spontaneous Emission under Object Stimulus Interaction. The interaction with the computer would look like this:

DESCRIPTOR: 5 (return)
SENSOR: 1 (return)
FUNCTION: 1 (return)
FUNCTION: DONE (return)
SENSOR: DONE (return)
DESCRIPTOR: 7 (return)

OBJECT: 2 (return)
OBJECT-STIMULUS INTERACTION: HELP (return)

1. ACTIVE OBJECT
2. PASSIVE OBJECT

OBJECT-STIMULUS INTERACTION: 1 (return)
ACTIVE OBJECT: 3 (return)
ACTIVE OBJECT: DONE (return)
OBJECT-STIMULUS INTERACTION: DONE (return)
OBJECT: DONE (return)

DESCRIPTOR: 6 (return)
ENVIRONMENT: 1 (return)
DESCRIPTOR AT SENSOR: 4 (return)
DESCRIPTOR AT SENSOR: DONE (return)
ENVIRONMENT: DONE (return)

DESCRIPTOR: DONE (return)

Then program will now print the resultant template on the CRT (and the printer, if requested):

```
SEARCH OVER THE FOLLOWING
     ---SENSOR DESCRIPTORS---
     5.1  FUNCTION
          NAVIGATION
     ---ENVIRONMENT DESCRIPTORS---
     6.1  AT SENSOR
          UNDERWATER
     ---OBJECT DESCRIPTORS---
     7.2  OBJECT-STIMULUS INTERACTION
          SPONTANEOUS EMISSION
     OK (Y OR N)?  N (return)
     DESCRIPTOR:  6 (return)
     ENVIRONMENT:  2 (return)
     DESCRIPTOR AT OBJECT:       4      (return)
     DESCRIPTOR AT OBJECT:  DONE (return)
     ENVIRONMENT:  DONE (return)
     DESCRIPTOR:  DONE (return)
```

The program will now print out the template with all four of our requested items. As soon as a "Y" answer is given to the OK question the search will begin.

To get a specific record, type:

```
: DESCRIPTOR?  KEY (Return)
: KEY NUMBER?  260 (Return)
: DESCRIPTOR?  DONE (Return)
```

This procedure will search the data and print when it gets to the record with key Number 260. It does not stop, but will continue through the data base to the end.

To get a print-out of all the data,

```
: DESCRIPTOR? NONE (Return)
: DESCRIPTOR? DONE (Return)
```

The program has no entries in the template and therefore all records in the data base are acceptable. All records in the data base will appear on the CRT (and the printer) in long or short form as was initially specified.

## B.2 Short Form Sensor List

Example Listing

Program Output Reference Line Number*

Computer File Number

Sensor Key Number in Data Base

```
68  ( 68 ). KEY IS 66        UW SOUND MEASUREMENT
NRL/USRD H-48 HYDROPHONE
```

Sensor System Title

Specific Use

*NOTE: In this consecutive listing of the data base the program output reference line number is the same as the file number since the files are searched in consecutive order. This is not true when a specific template search is made.

The sensor key number is used to cross-reference the taxonomy information for a particular sensor with the corresponding abstract or specification information contained in Appendices C and D. Sensor key numbers occasionally contain letter designators. These refer to separate components of a multi-sensor system which is usually in one mechanical package. Editing and changes within the data base have resulted in some out-of-sequence key numbers. This does not affect the computer searches.

SHORT FORM SENSOR LIST

SEARCH OVER THE FOLLOWING
(IN 'OR' MODE)

1 ( 1 ), KEY IS 1 ACOUSTIC NAVIGATION
PULSE-DOPPLER NAVIGATION SYSTEM

2 ( 2 ), KEY IS 2 DIVER COMMUNICATION
UNDERWATER BINAURAL COMMUNICATION

3 ( 3 ), KEY IS 3 REMOTE TEMP. MEAS.
SATELLITE MEASUREMENT OF SURFACE TEMPERATURE

4 ( 4 ), KEY IS 4 LASER-EXCITED RAMAN BACKSCATTERI
REMOTE DETECTION OF OIL SPILLS

5 ( 5 ), KEY IS 5 SEA ICE IMAGERY
SATELLITE IMAGERY FOR SEA ICE

6 ( 6 ), KEY IS 6 RADIOMETER FOR REMOTE SENSING
UHF RADIOMETER

7 ( 7 ), KEY IS 7 SURFACE CURRENT MEASUREMENT
HF RADIO MEASUREMENT AT SURFACE CURRENT

8 ( 8 ), KEY IS 8 VERTICAL CURRENT MEASUREMENT
VERTICAL CURRENT METER

9 ( 9 ), KEY IS 9 CURRENT MEASUREMENT
INCLINOMETER ARRAY

10 ( 10 ), KEY IS 10 TEMPERATURE PROFILE MEASUREMENT
BEAR BUOY THERMISTER CHAIN

11 ( 11 ), KEY IS 11 DETERMINE SIGNAL DIRECTION
NON SCANNING SONAR

12 ( 12 ), KEY IS 12 VOICE OPERATED KEYER
VOICE OPERATED KEYER

13 ( 13 ), KEY IS 13
WAVE HEIGHT METER

14 ( 14 ), KEY IS 14 CURRENT AND TURBULENCE MEAS.
3 AXIS CURRENT METER

15 ( 15 ), KEY IS 15 OCEAN CURRENT MEAS.
ECC MODEL 301 CURRENT METER

16 ( 16 ), KEY IS 16 REMOTE SALINITY MEASUREMENT
REMOTE MEASUREMENT OF SALINITY

17 ( 17 ), KEY IS 17 MICROWAVE RADIOMETER
MICROWAVE EMISSION FROM ICE

18 ( 18 ), KEY IS 18 WAVE-SPECTRA MEASUREMENT
BISTATIC RADAR OCEAN WAVE OBSERVATION

19 ( 19 ), KEY IS 19 WATER FLOW MEASUREMENT

PRESSURE DIFFERENTIAL FLOWMETER

20 ( 20 ), KEY IS 20 ACOUSTIC POSITION LOCATING
FLOAT TRACKING SYSTEM

21 ( 21 ), KEY IS 21 TEMPERATURE PROFILE MESUREMENT
DIGITAL XBT SYSTEM

22 ( 22 ), KEY IS 22 SALINITY MEASUREMENT
ON-LINE CONDUCTIVITY MEASUREMENT

23 ( 23 ), KEY IS 23 UNDERWATER PHOTOGRAPHY
FREE VEHICLE DROP CAMERA

24 ( 24 ), KEY IS 24
HORIZONTAL PLANAR ARRAY FOR SONOBUOYS

25 ( 25 ), KEY IS 25
DOPPLER SONAR INVESTIGATION AND EVALUATION

26 ( 26 ), KEY IS 26
DOPPLER SONAR DETECTION OF SWIMMERS

27 ( 27 ), KEY IS 27
MAGNETIC GRADIOMETER AND MAGNETOMETER MEASUREMENTS

28 ( 28 ), KEY IS 29
ARCTIC PORTABLE SURVEILLANCE SYSTEM

29 ( 29 ), KEY IS 30 GAMMA RAY TRANSMISSION SPECTROME
NUCLEAR MEASURING TECHNIQUES IN MINING

30 ( 30 ), KEY IS 31 DEEP WATER GROUND SPEED MEASUREM
SPERRY PARAMETRIC ARRAY DOPPLER SONAR

31 ( 31 ), KEY IS 32 TEMP MEASUREMENT
TERMISTOR CHAIN FOR U.W. TEMP. MEASUREMENT

32 ( 32 ), KEY IS 33 SATELLITE IMAGERY
ERTS-1 OCEAN OBSERVATION

33 ( 33 ), KEY IS 34 SEDIMENT TRANSPORT STUDY
ACOUSTIC TRANSPONDING PEBBLES/SIDESCAN SONAR

34 ( 34 ), KEY IS 35 ORGANIC CARBON MEASUREMENT
OIL-WATER POLLUTION MONITORING SYSTEM

35 ( 35 ), KEY IS 36 FISH TRACKING
AUTO. ELECTRONIC FISH TRACKING SYSTEM

36 ( 36 ), KEY IS 37 WATER DRIFT TRACKING
ACOUSTIC TRACKING OF WOODHEAD DRIFTERS

37 ( 37 ), KEY IS 38 FISH TARGET STRENGTH MEASUREMENT
DUAL BEAM FISH TARGET STRENGTH MEASUREMENT

38 ( 38 ), KEY IS 39 CURRENT MESUREMENT
LONG TERM CURRENT MEASUREMENT SYSTEM

39 ( 39 ), KEY IS 40 MULTICHANNEL MICROWAVE AUDIOMETE

SEASAT A SCANNING MULTICHANNEL MICROWAVE RADIOMETER

40 ( 40 ), KEY IS 41 RADAR ALTIMETER
DESIGN AT SEASAT-A RADAR ALTIMETER

41 ( 41 ), KEY IS 42 SUBMERGED CABLE TRACKING
VECTOR MAGNEMOMETER SYSTEM

42 ( 42 ), KEY IS 43 RADAR IMAGERY
SEASAT-A SYNTHETIC APERATURE RADAR

43 ( 43 ), KEY IS 44 DUMPED MATERIAL MONITORING
OCEAN DUMPING SURVEILLANCE SYSTEM

44 ( 44 ), KEY IS 45 WATER CURRENT METER
ELECTROMAGNETIC CURRENT METER

45 ( 45 ), KEY IS 46 INTERNAL WAVE MEASUREMENTS
TEMP. MEASUREMENT ARRAY FOR INTERNAL WAVE OBSERVATION

46 ( 46 ), KEY IS 47 XRAY FLOURESCENCE SPECTROMETER
ANALYSIS OF MARINE SEDIMENTS BY XRAY FLOURESCENCE

47 ( 47 ), KEY IS 48A MICROSTRUCTURE IMAGING
TEMP + SALINITY MICROPROFILER

48 ( 48 ), KEY IS 48B SALINITY MEASUREMENT
TEMP + SAL MICRO PROFILER

49 ( 49 ), KEY IS 48C TEMPERATURE MEASUREMENT
TEMP + SAL MICRO PROFILER

50 ( 50 ), KEY IS 49 PRECISION BATHYMETRY
HIGH RESOLUTION AUTO. CHARTING SYSTEM FOR OCEAN FLOOR

51 ( 51 ), KEY IS 50 MEAS. OF LIGHT SCATTER. & ABSORP
TOW-TYPE LASER ABSORPTION METER

52 ( 52 ), KEY IS 51 PHOTOGRAPH OCEAN FLOOR
UNDERWATER CAMERA AND STROBE

53 ( 53 ), KEY IS 28
INTEGRATED SENSOR SYSTEM FOR BURIED ORDNANCE

54 ( 54 ), KEY IS 52 MONITOR FISH MIGRATION
ACOUSTIC FISH COUNTER

55 ( 55 ), KEY IS 53 CURRENT PROFILE MEASUREMENT
FREE FALL ELECTROMAGNETIC CURRENT METER

56 ( 56 ), KEY IS 54 LOW FREQ AIR PRESSURE FLUCTUATI
AIR PRESSURE MEASUREMENT NEAR SEA SURFACE

57 ( 57 ), KEY IS 55 DISSOLVED OXYGEN MEASUREMENT
IN SITU MOLECULAR OXYGEN PROFILER

58 ( 58 ), KEY IS 56 MEASUREMENT OF TIDE HEIGHT
IN SITU TIDE GAGE

59 ( 59 ), KEY IS 57 MEASURE TIDAL PRESSURE

TIDAL PRESSURE MEASUREMENTS

60 ( 60 ), KEY IS 58 U.W.DATA TELEMETRY & INSTMT. CON
TELEMETRY RECEIVER AND ACOUSTIC COMMAND SYSTEM

61 ( 61 ), KEY IS 59 DETECT DENSITY OF FLURSNT CHEMLS
VARIOSENS CHLOROPHYLL AND FLUORESCENCE DETECTOR

62 ( 62 ), KEY IS 60 U.W. COMMUNICATION
U.W. COMMUNICATION BY ELECTRIC CURRENT

63 ( 63 ), KEY IS 61 WATER PRESSURE MEASUREMENT
SELF CONTAINED TIDE GAGE

64 ( 64 ), KEY IS 62 DEPTH MEASUREMENT
C.T.D. MICROPROFILER

65 ( 65 ), KEY IS 63 SEDIMENT DENSITY PROFILER
BULK DENSITY MEASMNT BY GAMMA RAYS

66 ( 66 ), KEY IS 64 REMOTE PHOTOGRAPHIC SENSING
MULTISPECTRAL PHOTOGRAPHIC SENSING

67 ( 67 ), KEY IS 65 EARTHQUAKE MEASUREMENTS
OCEAN BOTTOM SEISMOGRAPH

68 ( 68 ), KEY IS 66 UW SOUND MEASUREMENT
NRL/USRD H-48 HYDROPHONE

69 ( 69 ), KEY IS 67 ELECTRIC CURRENT COMMUCATN
CONDUCTION CURRENT SIGNALLING

70 ( 70 ), KEY IS 68 LIGHT SCATTERING MEASUREMENT
PHOTOGRAPHIC NEPHELOMETER

71 ( 71 ), KEY IS 69 LIGHT RADIANCE MEASUREMENT
UNDERWATER RADIANCE SCANNER

72 ( 72 ), KEY IS 70 LUGHT ATTENUATION MEASUREMENT
TRANSMISSOMETER

73 ( 73 ), KEY IS 71 LIGHT ATTENUATION MEASUREMENT
BEAM ATTEN. METER

74 ( 74 ), KEY IS 72 LIGHT ATTENUATION MEASUREMENT
EXPENDABLE BATHYPHOTOMETER

75 ( 75 ), KEY IS 73 DEEP BOTTOM PROFILER
BOTTOM PROFILE

76 ( 76 ), KEY IS 74 AMBIENT NOISE MEASUREMENT
ACODAC

77 ( 77 ), KEY IS 75 SOUND SOURCE LOCATING
4-HYDROPHONE ARRAY

78 ( 78 ), KEY IS 76 OPTICAL RADAR
LIDAR AS AN OCEAN PROBE

79 ( 79 ), KEY IS 77 BUBBLE DENSITY MEASUREMENT

MEASMNT OF MICROBUBBLE CONCENTRATN

80 ( 80 ), KEY IS 78 SUBMARINE COMMUNICATION
ELF COMMUCATN SYSTEM DESIGN

81 ( 81 ), KEY IS 79 LIGHT DISTRIBUTION MEASUREMENT
RADIANCE DISTRIBUTION CAMERA

82 ( 82 ), KEY IS 80 INSTRUMENT OPERATION OBSERVATION
DEEP SEA COREHEAD CAMERA

83 ( 83 ), KEY IS 81 SPRAY DROPLET MEASUREMENT
LIDAR MEASUREMENT OF SPRAY PLUMES

84 ( 84 ), KEY IS 82 OPTICAL TELEMETRY
LIGHT COUPLED INFO TRANSMISSION

85 ( 85 ), KEY IS 83 STEREO TV
UNDERWATER STEREO TV

86 ( 86 ), KEY IS 84 SEISMIC-ACOUSTIC SIGNALLING
COMMUNICATION THROUGH ICE

87 ( 87 ), KEY IS 85 SPECTRAL RADIOMETRY
TRW SYSTEMS OCEAN COLOR SENSOR

88 ( 88 ), KEY IS 86 INTRUSION DETECTOR
SEISMMIC POINT SENSOR

89 ( 89 ), KEY IS 87 INTRUSION WARNING
WIRE IN TUBE SENSOR

90 ( 90 ), KEY IS 88 TUBID WATER IMAGING
SONIC CAMERA WITH 10' RANGE AND REAL TIME DISPLAY

91 ( 91 ), KEY IS 89
OPTICAL LOCALIZATION OF DEEP UW TARGETS

92 ( 92 ), KEY IS 91 ICE THICKNESS MEASUREMENT
FM RADAR ICE THICKNESS MEASUREMENT

93 ( 93 ), KEY IS 90A OIL SPILL DETECTION
AIRBORNE OIL SURVEILLANCE SYSTEM (IR&UV LINE SCANNER)

94 ( 94 ), KEY IS 90B OIL SPILL DETECTION
AIRBORNE OIL SURVEILLANCE SYSTEMM (LOW LIGHT TV)

95 ( 95 ), KEY IS 90C OIL SPILL DETECTION
AIRBORNE OIL SURVEILLANCE SYSTEM (MICROWAVE IMAGER)

96 ( 96 ), KEY IS 90D OIL SPILL DETECTION
AIRBORNE OIL SURVEILLANCE SYSTEM (SIDELOOKING RADAR)

97 ( 97 ), KEY IS 101 DIVER VEHICLE SONAR
OBSTACLE AVOIDANCE SONAR (AN/WQS-1)

98 ( 98 ), KEY IS 92 ICE CLASSIFICATION
ICE TYPE IDENT. SYST.

99 ( 99 ), KEY IS 93 LONG RANGE RADAR MEAS.

HIGH RESOLUT. OTH-B RADAR

100 ( 100 ), KEY IS 94 OCEAN PHOTOGRAPHY
FILMS FOR IMPR. OCEAN IMAGING

101 ( 101 ), KEY IS 95 SEARCH & RESCUE, SURVEILLANCE
SEA SURFACE MARKER AGENTS

102 ( 102 ), KEY IS 96 TEMP.PROFILE MEAS.UNDERWAY
A LT.WT. TOWED TEMP. ARRAY

103 ( 103 ), KEY IS 97 WATER VELO. PROFILE MEAS.
VELO.PROFILER USING DOPPLER PRINC.

104 ( 104 ), KEY IS 98 LOW-FREQ. SOUND DETECT.
FIBER-OPTIC DETECT.OF SOUND

105 ( 105 ), KEY IS 99 REMOTE WATER QUAL.MEAS.
RAMAN SPECTRA OF H2O &SO4 IN SEAWATER

106 ( 106 ), KEY IS 100 REMOTE TEMP.MEAS.
MEAS. OF OCEAN TEMP. FROM DEPOLARIZATION IN RAMAN SCATTERING

107 ( 107 ), KEY IS 102 ELECTRIC CURRENT COMM.
COMM.THROUGH A CONDUCTING MEDIUM

108 ( 108 ), KEY IS 103 MECH.OIL DETECTOR
FLOATING OIL SLICK DETECTOR

109 ( 109 ), KEY IS 104 OIL POLLUTION MONITOR
OIL DETECTION BUOY SYSTEM

110 ( 110 ), KEY IS 105 SPILL THICKNESS MEAS.
MEAS.OF OIL-SPILL DIST.BY MICROWAVE RADIOMTRY.

111 ( 111 ), KEY IS 106 DEEP TOWED MAGNETOMETER
NRL MAGNETOMETER

112 ( 112 ), KEY IS 107 REMOTE POLLUTION MEAS.
LASER RAMAN SPECTROSCOPY FROM A REMOTE PLATFORM

113 ( 113 ), KEY IS 108 SUBMARINE COMMUNICATION
ELF COMMUNICATION SCHEME

114 ( 114 ), KEY IS 109 OIL SPILL DETECTION
OIL-ON-WATER SENSOR

115 ( 115 ), KEY IS 110 NOISE-CANCELLING MICROPHONE
DIVER COMMUNICATION MICROPHONE DEVELOPMENT

116 ( 116 ), KEY IS 111 TV OIL-SPILL MONITOR
VIDEO SYST.FOR OIL-SPILL SURVEIL.

117 ( 117 ), KEY IS 112A OIL CONTENT MEAS.
OIL-IN-WATER MONIT.(BAIRD-ATOMIC)

118 ( 118 ), KEY IS 112B OIL CONTENT MEAS.
OIL-IN-WATER MONITOR (G.E. ENVVIRO-CONTROL)

119 ( 119 ), KEY IS 113 ACOUSTIC IMAGING

ACOUSTIC IMAGING SYSTEM

120 ( 120 ), KEY IS 114 OPTICAL IMAGING
ADVANCED UNDERWATER OPTICAL IMAGING SYSTEMS

121 ( 121 ), KEY IS 115 ACOUSTIC DATA RECORDING
MOORED ACOUSTIC BUOY SYSTEM

122 ( 122 ), KEY IS 116
SWIMMER DETECTION BY DOPPLER SONAR

123 ( 123 ), KEY IS 117 POLLUTION SURVEILLANCE
BUOY-MOUNTED HYDROCARBON SENSORS

124 ( 124 ), KEY IS 118 SATELLITE MONITORING
OIL SPILL DETECTION USING ERTS-1

125 ( 125 ), KEY IS 119
MAGNETIC SENSOR SUBMARINE SURVEILLANCE

126 ( 126 ), KEY IS 120
EVALUATION OF INFRA-RED & TV SENSORS

127 ( 127 ), KEY IS 121 CURRENT MEASUREMENT
LOW VELOCITY ELECTROSTATIC CURRENT METER

128 ( 128 ), KEY IS 122 DEEP OCEAN TELEVISION
CABLE TV SYSTEM

129 ( 129 ), KEY IS 123 OCEAN WAVE MEASUREMENT
RADAR WAVE SENSOR

130 ( 130 ), KEY IS 124 WAVE HEIGHT MEAS.
WAVE AMPLITUDE MEASURING BUOY (SHORE RECORDING)

131 ( 131 ), KEY IS 125 ACOUSTIC IMAGING
HOLOGRAPHIC IMAGING SYSTEM

132 ( 132 ), KEY IS 126 SEDIMENT PROPERTY MEAS.
PENETROMETER SYSTEM

133 ( 133 ), KEY IS 127 FISH STOCK MEAS.
HYDROACOUSTIC FISH ASSESSMENT SYST

134 ( 134 ), KEY IS 128
PORTABLE OBJECT LOCATOR SONAR

135 ( 135 ), KEY IS 129 MICROWAVE WIND SPEED MEAS.
SEA SAT-A SATELLITE SCATTEROMETER

136 ( 136 ), KEY IS 130 CURRENT METER
ACOUSTIC CURRENT METER

137 ( 137 ), KEY IS 131 AMBIENT NOISE MEAS.
H62 HYDROPHONE

138 ( 138 ), KEY IS 132 INFRA-RED DETECTION
PHOTO CONDUCTIVE (Hg, Cd, Te) INFRA-RED DETECTORS

139 ( 139 ), KEY IS 133 INFRARED DETECTION

Li Ta O3 PYROELECTRIC INFRARED DETECTOR

140 ( 140 ), KEY IS 134 ICE TRACKING
AIR DROPABLE RAMS BUOY

141 ( 141 ), KEY IS 135 MEAS. IR ABSORPTION OF OIL
HORIBA OIL CONTENT MONITOR

142 ( 142 ), KEY IS 136 TEMPERATURE PROFILE MEAS
BATHYTHERMOGRAPH

143 ( 143 ), KEY IS 137 SATELLITE BUOY TRACKING
COSRAMS TRACKING BUOY

144 ( 144 ), KEY IS 138 SENSOR-SATELLITE TELEMTRY
SYNRAMS ICE STATION

145 ( 145 ), KEY IS 139 DEPTH FINDER
DIGITAL DEPTH SOUNDER

146 ( 146 ), KEY IS 140 SPEED INDICATION
DOPPLER SPEED LOG

147 ( 147 ), KEY IS 141 BOTTOM SURVEYING
CORRELATION ECHO SOUNDER PROCESSOR

148 ( 148 ), KEY IS 142 FISH LOCATION
L.F. SCANNING SONAR AND RECORDER

149 ( 149 ), KEY IS 143 DYNAMIC SHIP POSIT.CONTROL
HONEYWELL RS-7 ACOUSTIC POSITION INDICATOR

150 ( 150 ), KEY IS 144 WATER LEVEL MEAS.
AANDERAA WATER LEVEL RECORDER, 2069, TG-4 .

151 ( 151 ), KEY IS 145 PRECISION NAVIGATION
O.R.E. OCEAN NAVIGATION SYSTEM MODEL 6000

152 ( 152 ), KEY IS 146 VELOCITY MEAS.
SPERRY DOPPLER SONAR DOCKING SYST.

153 ( 153 ), KEY IS 147 SUB BOTTOM PROFILING
O.R.E. SUB BOTTOM PROFILING SYSTEM, MODEL 1036

154 ( 154 ), KEY IS 148A LAND-SEA INTERFACE DEF.
NIMBUS-G SATELLITE,COASTAL ZONE COLOR SCANNER

155 ( 155 ), KEY IS 149 DETECT.OF CHARGED PARTICLES
CHARGED PARTICLE DETECTORS

156 ( 156 ), KEY IS 150 WEATHER OBS.&MEAS.
NIMBUS RADIOMETER

157 ( 157 ), KEY IS 151 BOTTOM SURVEYING&CHARTING.
SIDE SCAN SONAR

158 ( 158 ), KEY IS 152 NAVIG.FOR SUBMERSIBLES
WESMAR SCANNING SONAR FOR SUBMERSIBLES

159 ( 159 ), KEY IS 153 TRACKING & LOCATING OBJECTS

WESMAR T400 DUAL FREQ. TRANSPONDER

160 ( 160 ), KEY IS 154 BATHYMETRY
HIGH POWER TRANSDUCER

161 ( 161 ), KEY IS 155 SALINITY MEAS.
REFRACTOMETER/SALINOMETER

162 ( 162 ), KEY IS 156 MOORING RELEASE MECHANISM
SEDAR RELEASE MECHANISM, TYPE 569

163 ( 163 ), KEY IS 157 TENSION MEASUREMENT
TYPE 210 LOAD CELL

164 ( 164 ), KEY IS 158 LOW LIGHT OBSERVATION
MINIATURE FORWARD LOOKING IR SENSOR

165 ( 165 ), KEY IS 159 GRAVITY WAVE MEAS.
OPTICAL WAVE SPECTRA MEAS.

166 ( 166 ), KEY IS 160 REMOTE SENSING
MULTI-SPECTRAL SCANNERS

167 ( 167 ), KEY IS 161A MEASURE CONDUCTIVITY
MODEL U7 WATER QUALITY CHECKER (CONDUCTIVITY SENSOR)

168 ( 168 ), KEY IS 161B TURBIDITY SENSOR
MODEL U7 WATER QUALITY CHECKER (TURBIDITY SENSOR)

169 ( 169 ), KEY IS 161C DISSOLVED OXYGEN MEAS.
MODEL U7 WATER QUALITY CHECKER (OXYGEN SENSOR)

170 ( 170 ), KEY IS 161D TEMPERATURE MEASUREMENT
MODEL U7 WATER QUAL.CHECKER(TEMP.SENSOR)

171 ( 171 ), KEY IS 161E PH MEASUREMENT
MODEL U7 WATER QUAL.CHECKER(PH SENSOR)

172 ( 172 ), KEY IS 162 POLLUTION DETECTION
WATER SAMPLE ELECTRODES

173 ( 173 ), KEY IS 163A PH MEASUREMENT
TYPE 169 WATER QUALITY MON. SYSTEM (PH)

174 ( 174 ), KEY IS 164 HIGH RESOLUTION SONAR
KLEIN SIDE-SCAN SONAR SYSTEM

175 ( 175 ), KEY IS 165 SURFACE CURRENT MEAS.
CURRENT DROGUE WITH DYE

176 ( 176 ), KEY IS 166 SURFACE CURRENT MEAS.
CURRENT DROGUE WITH RADIO AND DYE

177 ( 177 ), KEY IS 167 WATER DRIFT TRACKING
SOFAR PROBE

178 ( 178 ), KEY IS 168 CURRENT METERS
500 SERIES ELECTROMAGNETIC H2O CURRENT MTRS.

179 ( 179 ), KEY IS 169 FLOW METER

MODEL 201 WATER FLOW MEASUREMENTS

180 ( 180 ), KEY IS 170 UNDERWATER TV CAMERA
MODEL 1600 HR UNDERWATER TV CAMERA

181 ( 181 ), KEY IS 171 DEPTH MEASUREMENTS
MODEL 9057 SONAR SOUNDING SET

182 ( 182 ), KEY IS 172 HYDROPHONE
MODEL 6042 HYDROPHONE

183 ( 183 ), KEY IS 173 SPEED AND DISTANCE LOG
CROSSTRAK DOPPLER SPEED LOG

184 ( 184 ), KEY IS 174 U.W.LOCATION&NAVIG.SYST.
HIGH RESOLUTION SCANNING SONAR SYSTEM

185 ( 185 ), KEY IS 175A WELL REENTRY
COMBINED SONAR/TV (SONAR)

186 ( 186 ), KEY IS 176 HIGH RESOLUTION SONAR
OBSTACLE AVOIDANCE SONAR SYSTEM

187 ( 187 ), KEY IS 177 DIRECTION INDICATOR
SOLID STATE COMPASS

188 ( 188 ), KEY IS 178 CURRENT VELOCITY
CURRENT METER

189 ( 189 ), KEY IS 179 MONITOR WAVE DIRECTION
WAVE DIRECTION RECORDER (IN SITU)

190 ( 190 ), KEY IS 180 WATER QUAL.MEAS.
DUAL POLARIZATION LASER BACKSCATTER SYST.

191 ( 191 ), KEY IS 181 UNDERWATER TELEPHONE
DIVERS COMMUNICATION SYSTEM

192 ( 192 ), KEY IS 182
DEFENSE AGAINST SWIMMER ATTACK (SURFACE)

193 ( 193 ), KEY IS 183
SUBMARINE-TO-SUBMARINE COMMUNICATIONS

194 ( 194 ), KEY IS 184 MAGNETIC HEADING SENSOR
MAGNETOMETER COMPASS

195 ( 195 ), KEY IS 185 CONTROLLED MARKER
HELLE CALL BUOY

196 ( 196 ), KEY IS 186 INSTR.RECALL RELEASE SYST.
HELLE REUSABLE RECALL SYST/W MECH. RELEASE

197 ( 197 ), KEY IS 187A PINGER RECEIVER (&LOCATOR)
DIVER PINGER RECEIVER

198 ( 198 ), KEY IS 187B PINGER LOCATOR
HELLE PING POINTER

199 ( 199 ), KEY IS 188 PINGER LOCATOR&RECVER.

DIRECTIONAL ANTENNA MODEL 6500

200 ( 200 ), KEY IS 189 PINGER RECEIVER & LOCATOR
DIRECTIONAL ANTENNA MODEL 6555

201 ( 201 ), KEY IS 190 RADIO DIRECTION FINDING
SONOBUOY LOCATION SYSTEM (ARA-50)

202 ( 202 ), KEY IS 191 SEA FLOOR RESISTIVITY MEAS.
MARINE ELECTROMAGNETIC SOUNDING

203 ( 203 ), KEY IS 192 ICE THICKNESS MEASUREMENT
AIRBORNE SEA-ICE THICKNESS PROFILING

204 ( 204 ), KEY IS 193 REMOTE TEMP.MEAS.
SEAWATER TEMP. MEASUREMENT USING RAMAN SPECTRA

205 ( 205 ), KEY IS 194 SEDIMENT TRANSPORT MEAS.
STRAIN GAGE SEDIMENT MIGRATION MONITORS

206 ( 206 ), KEY IS 195 REMOTE SOUND MEAS.
REMOTE SENSING OF UNDERWATER SOUND

207 ( 207 ), KEY IS 196 MICROWAVE SALINITY MEAS.
TESTING TECHNIQUE FOR REMOTELY MEASURING SALINITY IN A ESTUARY

208 ( 208 ), KEY IS 197 OIL SPILL DETECTION
FLUORESCENCE OIL SPILL DETECTOR

209 ( 209 ), KEY IS 198A DIVER PHYSICAL COND.MONITOR
MULTICHANNEL UNDERWATER TELEMETRY SYSTEM (DIVER EKG MEAS.)

210 ( 210 ), KEY IS 198B DIVER TEMP.MONITOR
MULTICHANNEL UNDERWATER TELEMETRY SYSTEM (BODY TEMP. MEAS.)

211 ( 211 ), KEY IS 199 OBSERV.OCEANIC DENSITY STRUCT.
LARGE APERTURE ACOUSTIC ARRAY

212 ( 212 ), KEY IS 200 TRACE ELEMENT MEAS.
DETERMINATION OF TRACE ELEMENTS IN SUB-NANOGRAM RANGE

213 ( 213 ), KEY IS 201 REMOTE ICE-THICKNESS MEAS.
POTENTIAL USE OF SATELLITE IR DATA FOR ICE THICKNESS MAPPING

214 ( 214 ), KEY IS 202 ICE-THICKNESS MEAS.
AIRBORNE IR IMAGERY OF ARTIC SEA ICE-THICKNESS

215 ( 215 ), KEY IS 203 UNDERWATER TO SATELLITE COMM.
OPTICAL COMM. BETWEEN UNDERWATER & SATELLITE TERMINALS

216 ( 216 ), KEY IS 204 OIL POLLUTION DETECTION
GAS CHROMOTAGRAPHIC TECH.FOR HYDROCARBONS IN SEA WATER

217 ( 217 ), KEY IS 205 IDENTIFYING FISHING AREAS
REMOTE SENSING OF OCEANIC GAMEFISH

218 ( 218 ), KEY IS 206 WATER POLLUTION MONITORING
ION-SELECTIVE MEMBRANE ELECTRODES

219 ( 219 ), KEY IS 207 SEARCH AND RESCUE

SOFAR

220 ( 220 ), KEY IS 208 MEASURE RADIATED NOISE
CHESAPEAKE INST. MOBILE UNDERWATER MEASUREMENT SYSTEM

221 ( 221 ), KEY IS 209 PASSIVE TOWED SONAR
CHESAPEAKE INST. LIGHT-WEIGHT TOWED ARRAY SONAR

222 ( 222 ), KEY IS 210 PASSIVE TOWED SONAR
CHESAPEAKE INST. AN/SQR-15 SONAR

223 ( 223 ), KEY IS 211 WATER POLLUTION DETECTION
BARRINGER RESEARCH LASER FLUOROSENSOR

224 ( 224 ), KEY IS 212 MAGNETIC ANOMALY DETECTION
MAGNETOMETER MODEL BM-123

225 ( 225 ), KEY IS 213 AERIAL PHOTOGRAPHY
ITEK KA-102A CAMERA SYSTEM

226 ( 226 ), KEY IS 214 HIGH RESOLUTION RADAR
TEXAS INSTR. AN/APS-116 RADAR

227 ( 227 ), KEY IS 215 MAGNETIC ANOMALY DETECTION
MAGNETOMETER AN/ASQ-81(V)

228 ( 228 ), KEY IS 216 CURRENT MEAS.
GEN. OCEANICS RECORDING CURRENT METER

229 ( 229 ), KEY IS 217 TRACE METAL DESCRIPTION
AUTOMATED MEASUREMENT OF METALS IN SEAWATER

230 ( 230 ), KEY IS 218 MEASURE WAVE HEIGHT
TELEDYNE GEOTECH INFRARED OCEAN WAVE METER

231 ( 231 ), KEY IS 219 MAGNETIC FIELD MEAS.
S.H.E.CORP. SUPERCONDUCTING QUANTUM INTERFERENCE DEVICE

232 ( 232 ), KEY IS 220 ELECTROMAGNETIC PROFILING OF ICE
BARRINGER RESEARCH COTRAN PULSED ELECTROMAGENTIC DETECTOR

233 ( 233 ), KEY IS 269
WAKE DETECTION SYSTEM

234 ( 234 ), KEY IS 270
OPTICAL DETECTION OF A SUBMARINE

235 ( 235 ), KEY IS 271
UNDERWATER ACOUSTO-OPTICAL IMAGING

236 ( 236 ), KEY IS 272
ACOUSTIC DETECTION SYSTEM FOR BUOYS

237 ( 237 ), KEY IS 273
AIR/UNDERWATER LASER RADAR

238 ( 238 ), KEY IS 274
DEPLOYABLE ACOUSTIC/MAGNETIC ANOMALY DETECTOR

239 ( 239 ), KEY IS 275

MOORED SURVEILLANCE SYSTEM

240 ( 240 ), KEY IS 276
AN/SSQ-75 SONOBUOY

241 ( 241 ), KEY IS 277 UNDERWATER TRACKING OR LOCATING
WESMAR T210 TRANSPONDER

242 ( 242 ), KEY IS 278 L.F.ACOUSTIC DETECTION
AN/SSQ-57(VLAD) L.F.DIRECTIONAL SONOBUOY

243 ( 243 ), KEY IS 279 SATELLITE DISTRESS SIGNAL DETECT
SATELLITE BASED MARITIME SEARCH&RESCUE

244 ( 244 ), KEY IS 280 SPEED AND DISTANCE MEAS.
ELECTROMAGNETIC SHIPS LOG SYSTEM

245 ( 245 ), KEY IS 221 BUOY MOTION MEAS.
NSRDC BUOY MOTION MEASUREMENT SYSTEM

246 ( 246 ), KEY IS 222 MEASURE MICROBUBBLE SIZE DIST.
OCEAN MICROBUBBLE ACOUSTIC ANALYZER

247 ( 247 ), KEY IS 223 VALVE LEAK DETECTION
NSRDC ACOUSTIC VALVE LEAK DETECTOR

248 ( 248 ), KEY IS 224 UNDERWATER STRAIN MEAS.
RUBBER PROTECTED UNDERWATER STRAIN GAUGES

249 ( 249 ), KEY IS 225 SEISMIC WAVE MEAS.
ELECTRO TECH LABS MD-70 GEOPHONE

250 ( 250 ), KEY IS 226 COPPER POLLUTION DETECTION
COPPER ION SELECTIVE SENSOR

251 ( 251 ), KEY IS 227 TRACE METAL DETECTION
APPARATUS FOR DETERMINING COPPER IN WATER

252 ( 252 ), KEY IS 228 POLLUTION DETECTION
LASER SENSING SYSTEM FOR OIL SPILL DETECTION

253 ( 253 ), KEY IS 229 ICE DETECTION & CHRCTRZTN.
CHARACT. SEAICE & ICEBERGS USING X-L BAND SYNTH. APERATURE RADAR

254 ( 254 ), KEY IS 230
MULTISPECTRAL SCANNER FOR EARTH RESOURCES APPLICATIONS

255 ( 255 ), KEY IS 231 SYNTH.APERT.RADAR SHIP SURVEIL.
ANALYSIS OF GEORGES BANK RADAR IMAGERY

256 ( 256 ), KEY IS 232 U.W. PHOTOGRAPHY
BENTHOS BOOMERANG CAMERA MODEL 380 AND FLASH

257 ( 257 ), KEY IS 233 U.W. PHOTOGRAPHY
BENTHOS MODEL 371 DEEP SEA UTILITY CAMERA & MODEL 381 FLASH

258 ( 258 ), KEY IS 234 RADIO BEACON MARKER
O.A.R. ST-200 SUBMERSIBLE TRANSMITTER

259 ( 259 ), KEY IS 235 WATER HEIGHT MEAS.

O.A.R. VIBRATING WIRE PRESSURE TRANSDUCER

260 ( 260 ), KEY IS 236 DIRECTION FINDER
O.A.R. VHF BAND AUTOMATIC DIRECTION FINDER MODEL ADFS-320

261 ( 261 ), KEY IS 237 BEACON (FOR LOCATION)
O.A.R. SF-500 SERIES SUBMERSIBLE FLASHER

262 ( 262 ), KEY IS 238 UNDERWATER PHOTOGRAPHY
RANGE-GATED PHOTOGRAPHIC SYSTEM

263 ( 263 ), KEY IS 239 NON-ACOUSTIC DIVER COMM.
ELECTRIC DIVER COMMUNICATION

264 ( 264 ), KEY IS 240 LASER VELOCIMETER HYDROPHONE
ELECTRO-OPTIC HYDROPHONE

265 ( 265 ), KEY IS 241 TV TRANS. USING PARAMETRIC SOURC
UNDERWATER ACOUSTIC TELEVISION TRANSMISSION

266 ( 266 ), KEY IS 242 DIVER DECOMPRESSION TIMING
PNEUMATIC RESISTOR DECOMPRESSION METER

267 ( 267 ), KEY IS 243 TEMP.PROFILE MEAS.
SIPPICAN EXPENDABLE BATHYTHERMOGRAPH PROBES

268 ( 268 ), KEY IS 244 HIGH SPEED TEMP.PROFILE MEAS.
AIR DEPLOYED EXPENDABLE BATHYTHERMOGRAPH

269 ( 269 ), KEY IS 245 SYNTHETIC APERTURE RADAR SEARCH
GLOBAL SEARCH AND RESCUE

270 ( 270 ), KEY IS 246 COLIFORM POLLUTION DETECTION
IN SITU WATER-MONITORING SYST.

271 ( 271 ), KEY IS 247 DRIFTING BUOY TRACKING
STRIFFLER BUOY-LOCATION SYSTEM

272 ( 272 ), KEY IS 248 LONG RANGE TRACKING & TELMTRY.
BUOY-TRACKING WITH OVER-THE-HORIZON RADAR

273 ( 273 ), KEY IS 249 REMOTE LOCATION DETERMINATION
NAV SAT SYSTEM FOR BUOY LOCATION

274 ( 274 ), KEY IS 250 CURRENT VELOCITY MEAS.
WATER CURRENT METER

275 ( 275 ), KEY IS 251 A.S.W. SURVEILLANCE
MOORED COASTAL SURVEILLANCE SONOBUOY

276 ( 276 ), KEY IS 252 INTRUSION DETECTOR(FERROUS MAT.)
MAGNETIC POINT SENSOR

277 ( 277 ), KEY IS 253 SEISMIC REFRACTION SONOBUOY
SEISMIC SONOBUOY

278 ( 278 ), KEY IS 254 REMOTE BATHYTHERMOGRAPH
AN/SSQ-36, BT TRANSMITTER

279 ( 279 ), KEY IS 255 L.F. ACOUSTIC DETECTION

AN/SSQ-53A, DIRECTIONAL SONOBUOY

280 ( 280 ), KEY IS 256 REMOTE ACOUSTIC MEAS.
AN/SSQ-57A REFERENCE SONOBUOY

281 ( 281 ), KEY IS 257 AIRCRAFT-SUB COMMUNICATIONS
SPARTAN ELECTRONICS SUBMARINE COMMUNICATIONS SONOBUOY

282 ( 282 ), KEY IS 258 LONG TERM ACOUSTIC SURVEILLANCE
DATA RECORDING SONOBUOY

283 ( 283 ), KEY IS 259 RADIOACTIVITY MEAS.
AERIAL RADIAC SYSTEM AN/ADR-6

284 ( 284 ), KEY IS 260
AIRBORNE METAL-DETECTING RADAR (METRRA)

285 ( 285 ), KEY IS 261
VERTICAL LINE ARRAY DIFAR SONOBUOY

286 ( 286 ), KEY IS 262
AIRCRAFT-SUBMARINE COMMUNICATIONS BUOY

287 ( 287 ), KEY IS 263
UNDER ICE SONOBUOY SYSTEM

288 ( 288 ), KEY IS 264
ICE AREA PORTABLE SURVEILLANCE SYSTEM

289 ( 289 ), KEY IS 265
SHADOWGRAPH SWIMMER SONAR

290 ( 290 ), KEY IS 266
HIGH DEFINITION SWIMMER SONAR

291 ( 291 ), KEY IS 267
IR DETECTION OF SUB-GENERATED SURFACE EFFECTS

292 ( 292 ), KEY IS 268
SONAR FOR MINE DETECTION

293 ( 293 ), KEY IS 148B DATA RELAY & POSITON LOCATION
TIROS-N SATELLITE, DATA COLLECTION & PLATFORM LOCATION SYSTEM

294 ( 294 ), KEY IS 148C SEA SURFACE TEMP. MEAS.
TIROS-N SATELLITE, HIGH RESOLUTION RADIOMETER

295 ( 295 ), KEY IS 163B SALINITY MEASUREMENT
TYPE 169 WATER QUALITY MON. SYSTEM (SALINITY)

296 ( 296 ), KEY IS 163C TEMPERATURE MEASUREMENT
TYPE 169 WATER QUALITY MON. SYSTEM (TEMP.)

297 ( 297 ), KEY IS 175B WELL REENTRY
COMBINED SONAR/TV (TV)

298 ( 298 ), KEY IS 281 BIOLOGICAL PROTEIN ANALYSIS
ELECTROPHORESIS ANALYZER (ORTEC)

299 ( 299 ), KEY IS 282 PHYTOPLANKTON CONCENTRATION

FOUR COLOR LIDAR FLUOROMETER

300 ( 300 ), KEY IS 283 INTERNAL WAVE OBSERVATION
SATELLITE IMAGERY OF OCEAN SURFACE

301 ( 301 ), KEY IS 284 ELEMENTAL ANALYSIS
X-RAY FLUORESCENCE ANALYZER, ORTEC 6110, 6122

302 ( 302 ), KEY IS 285 CHEMICAL ANALYSIS
X-RAY MICROANALYSIS SYSTEM, ORTEC MODEL 6230

303 ( 303 ), KEY IS 286 LIVE/DEAD ORGANISM RATIO
ATP PHOTOMETER, JRB MODEL 2000

304 ( 304 ), KEY IS 287 ORGANIC CONTENT
PRECISION OXYGEN, CARBON, AND NITROGEN ANALYZERS

305 ( 305 ), KEY IS 288 pH
pH PROBE, HORIBA MODEL K-7

306 ( 306 ), KEY IS 289 OIL CONTENT
OIL CONTENT ANALYZER, HORIBA MODEL OMCA-200

FOUND 306 IN 306 RECORDS



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