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Remote Underwater Systems on Towed Vehicles

FIG. 1. RUFAS (Remote Underwater Fishery Assessment System) is a vane-controlled vehicle, flies with video and photographic cameras to record scallops during resource surveys.

The decline in the use of manned submersibles has been accompanied by the increased use of underwater, remote, towed vehicles.

(Abstract on next page)

FOR MANNED submersibles the population explosion that peaked two years ago was short-lived. Today most of them are on the blocks and are no longer in service. But the near-extinction of manned submersibles has not meant the extinction of underwater mapping. Some of the work they did is being carried on by remote, towed vehicles (Spiess, et al, 1967). Photographic and mapping systems which were developed and proved on manned submersibles were simply installed on unmanned vehicles. The work of these vehicles, and vehicles with photographic systems designed solely for remote towed vehicles, have both provided excellent data and photos for analysis.

Remote, underwater, towed vehicles such as Deep Tow of Scripps Institution of Oceanography and Ocean Floor Search Equipment of the Naval Research Laboratories have instrument suits designed for reconnaissance, search and survey, and in the course of their work take thousands of photographs of wreckage, artifacts, and the ocean bottom surrounding them. The work of these vehicles is well known in the oceanographic community.

A vehicle perhaps not so well known is the towed vehicle developed to assess the population of calico scallops in their natural habitat and to duplicate with a remote vehicle the kind of scallop survey conducted with the manned submersible PC3B *CUBMARINE* (Bullis, 1969). This vehicle, called RUFAS (Remote Underwater Fishery Assessment System) was developed by the National Marine Fishery Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), with the cooperative effort of the General Electric Company, Louis, Miss. (Figure 1).

RUFAS I is a towed, vane-controlled vehicle with an operational depth of 50 fathoms maximum (a recent modification will expand its depth range to 100 fathoms). An operator using a control console to observe pitch, roll, height above bottom and vane-angle readouts, controls two rear vanes to *fly* the vehicle about 5 to 7 feet above the bottom. Video and photographic cameras aboard the vehicle provide both the visual and photo-documented survey evidence of the scallop resource. The photographic data are then analyzed to produce resource location and concentration maps and presentations for release to the scallop fishing industry. The survey photographs provide a further advantage to the NMFS biologists who study the pictures for valuable behavior information on the scallops.

The TV camera used on the vehicle is a Hydro Products Model TC 150 camera with a Conrac monitor. The photographic camera is a Flight Research pulse/cine 35mm model IV-C, with a 400-foot external magazine. A cyclic timer-type intervalometer is used to vary the time interval from one second per frame to five seconds per frame, depending on the flight altitude and the speed of the vehicle. This remarkable system provides a film load sufficient to photograph an eight-hour transect at about two knots exposing one frame every five seconds (Benton, et al, 1971).

ABSTRACT: *The decline in the use of manned submersibles has been accompanied by the increased use of underwater, remote, towed vehicles. Two representative systems are* RUFAS *of the National Marine Fisheries Service, National Oceanic and Atmosphere Administration, and* TELEPROBE *of the U. S. Naval Oceanographic Office.*

RUFAS *is a towed remote vehicle and is vane-controlled. It was developed to survey scallop populations by means of television and photography.*

TELEPROBE, *also a remote vehicle, can be used for search and identification missions as well as for detailed surveys of bottom topography. It is equipped with side-scan sonar, magnetometer, twin-base tandem cameras, television, altitude sonar, and slant range transponder.*

Maps derived from this system show the sonar imagery, interpreted and corrected with photography, and orthographically plotted on large-scale bathymetric charts to portray the large and small topographic features.

Artificial lighting is provided for by a 400-watt sodium arc light for photography and a 400-watt dysposium iodide light for television, and both lights can be used simultaneously to supplement ambient light, or at night in darkness.

The success of RUFAS I in accomplishing the objective of near bottom population surveys in shallow water has proved the value of unmanned, controlled underwater vehicles. And it has led to a study investigating the possibility of expanding the capabilities of a RUFAS-type vehicle to accomplish bottom surveys in both deep and shallow water. This study, investigated by Richard D. Benton, Ph.D. of The Institute of Engineering Technology, Mississippi State University, and Wilber R. Seidel of the National Marine Fisheries Service, NOAA, has led to the conclusion that a RUFAS-type vehicle (RUFAS II) which can survey to a depth of 400 fathoms is technically feasible (ibid.). RUFAS II would be equipped with TV, movie, and still cameras, flood and strobe lights, forward-looking and directional sonars, and vehicle controls all telemetered using a time-sharing system. The vehicle would measure about 11 feet long, 5.5 feet wide, and 3.5 feet high and weighs about 1,000 pounds fully instrumented.

RUFAS can be correctly described as a single-purpose vehicle (i.e., to conduct fishery resource surveys), and, as such, it can be kept relatively simple. If the mission requirements of the vehicle become complex, the vehicle likewise becomes complex. A typical vehicle in this category is TELEPROBE, an unmanned towed vehicle of the Naval Oceanographic Office (NAVOCEANO) (Figure 2).

TELEPROBE is instrumented both for detailed surveys for the precise mapping of the ocean floor and search and for identification missions for the recovery or location of objects lost on the ocean floor (Daugherty, Jr., F. M., 1969). The vehicle, which weighs about 3,000 pounds when fully instrumented, is constructed of open framework to reduce its moment of inertia. It is towed at about 2.5 knots, and the vehicle is limited to a maximum depth of 20,000 feet by the instrument pressure cases (30,000 feet of cable is available). But this depth limitation prohibits survey of only about 2 percent of the total ocean floor.

Present instrumentation on TELEPROBE includes side-scan sonar, television, tandem 35 mm cameras, thalium iodide lights for TV and 250 watt-sec. strobe lights for photography, magnetometer, and altitude sonar, all of which can be controlled through the frequency multiplexing telemetry system. This medley of instruments combines to form the search and identification system. The magnetometer and side-scan sonar perform the

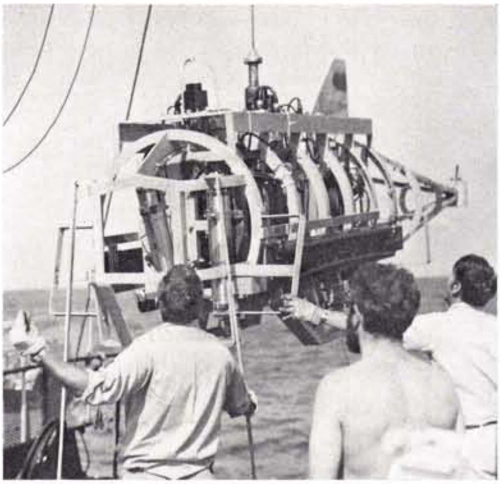


FIG. 2. TELEPROBE is a fully instrumented system for search survey, flies with delicate and precise winch control. The system consists of magnetometer, bimodal side-scan sonar, altitude sonar, television, altitude sonar, and slant-range transponder.

search and location task, whereas the TV and photographic cameras perform the visual identification and photographic documentation task (Figure 3).

If the techniques of search and identification are more rigorously imposed, TELEPROBE can provide survey data from which the most comprehensive and detailed maps of the ocean bottom can be produced. Successful surveys of this kind at depths less than 500 fathoms require precision electronic navigation systems with an accuracy better than ± 9 meters, ships with thrusters or bow props which can maneuver at slow speeds along closely spaced lines, winches with delicate control to maintain the vehicle at a uniform altitude above the bottom, and large-scale manuscripts to maintain the boat-sheet progress. At depths greater than 500 fathoms, transponder navigation to position the vehicle, and/or range-and-bearing data of the vehicle with respect to the survey ship are required.

The results are large-scale maps (nominally 600 feet per inch) which encompass areas of about 20 square miles and consist of delineated side-scan sonar imagery superimposed on special bathymetric charts of high precision with closely spaced contours (Figure 4).

The sonar imagery is obtained with a Westinghouse bimodal side-looking sonar mounted on TELEPROBE used in the long-range mode (2,500-foot sweep, 1,250 feet per side). The vehicle is towed at an altitude of 200 feet along parallel survey tracks which are 1200 feet apart. This spacing insures 100 percent overlap of sweeps and provides a complementary aspect of imagery.

Interpretation of the side-scan records is made possible by photography from TELEPROBE. The vehicle is equipped with two modified EG&G 35 mm cameras and two 250 watt-sec. strobe lights. The 35 mm cameras on TELEPROBE are calibrated to yield mensuration data by the same fixed-base method employed with manned submersibles (Pollio, 1969). The lighting is also the same. To reduce the effect of light backscatter the lights and camera must be separated, but the maximum distance available between cameras is 6 feet. To provide the greatest distance between cameras and lights, it is necessary to place camera and strobe side by side. A time delay of 1/25 sec. between cameras separates the light sources. The separation of light and camera is achieved by synchronizing the forward camera with the aft strobe and the aft camera with the forward strobe. The sole exception to the similarity between the systems is that the camera base on TELEPROBE is aligned fore and aft instead of port and starboard as on the manned submersibles.

To identify the features, the cameras are *flown* in areas of sonar imagery at an altitude of about 25 feet with the cameras cycled to take continuous overlapping pictures (usually about a 4-second interval). In this way, if the camera passes over areas of various sonar reflectivity, not only can the sonar reflectors be identified but the nature of the boundary can be described as well (Figure 5).

A simple method for determining the scale (and difference of altitude) has been developed and employed which enables oceanographers and those not skilled in photogrammetry to make the measurement. As the percentage of overlap (the parallax of the photograph format edge) is a function of the fixed base and varies with altitude, all that is necessary is simply to standardize the enlargement and to compute a graph or scale for the fixed relationship (Figure 6).

Where a more elaborate determination is required, the fixed base strengthens the bridging as described for manned submersibles (Pollio, 1971). Thus photogrammetric reduction of the photographs provides horizontal and vertical dimensions of both individual pairs and continuous strips. These data provide the side scan interpreter with qualitative and quantitative facts for positive delineation of the sonar imagery.

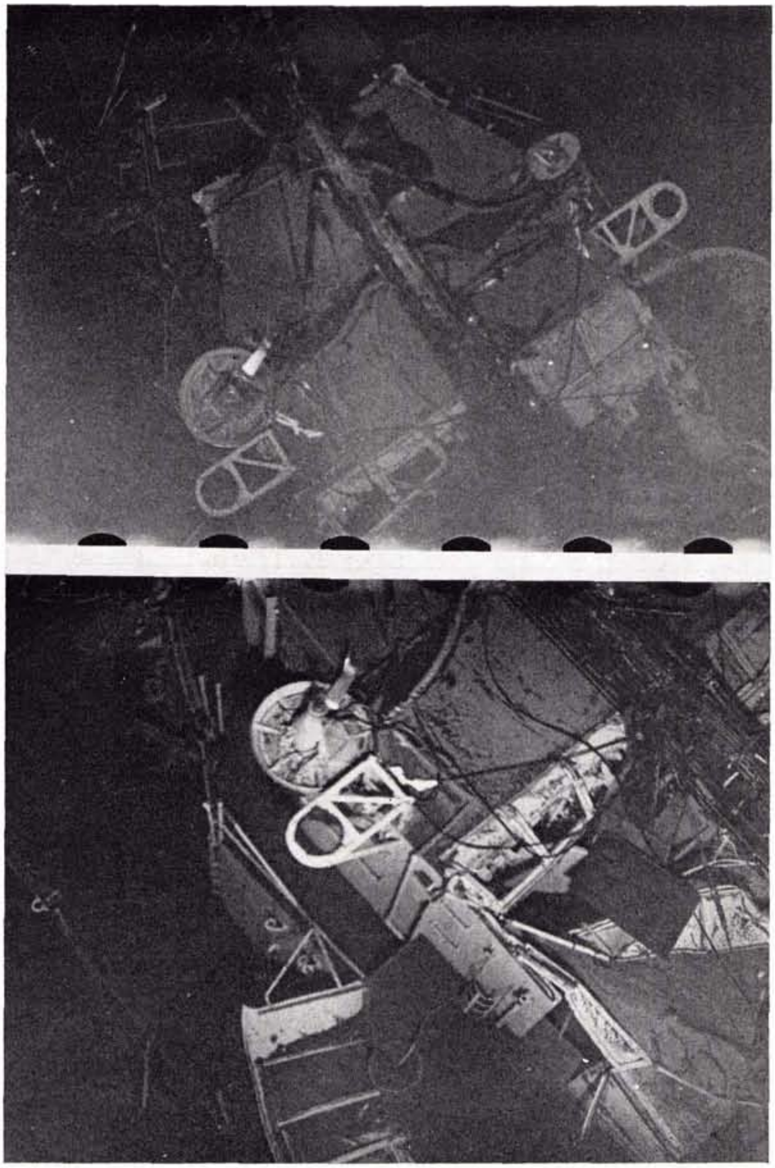


FIG. 3. These photos of a sunken destroyer attest to the ease of locating and positioning TELEPROBE over an artifact. In this instance, the magnetometer detected and located the hulk (30 to 30,000 gammas) from a distance of 1,000 feet. With both the side-scan sonar and magnetometer operating simultaneously, the camera was easily positioned.

Generally, in areas of high and rugged relief, the confused bottom land-forms are the image forming reflectors and, as such, are difficult to isolate and delineate on maps. But in areas of low relief rock outcrops are anomalous and stand out from an otherwise smooth bottom (Figure 7). Also, in low-relief areas the sonar imagery can be caused by a strong variation in impedance mismatch of the different sediments (rock contra soft sediment), by microtopography, and by high-frequency roughness (gravels, cobbles, and occasional boulders contra smooth specular reflection). Because in this situation the side-scan sonar imagery is anomalous to the generally-smooth bottom, the imagery can be classified by its prominence and its appearance on the record.

The symbol characteristics are chosen by the order of importance of the reflector. Images which indicate a natural topographic

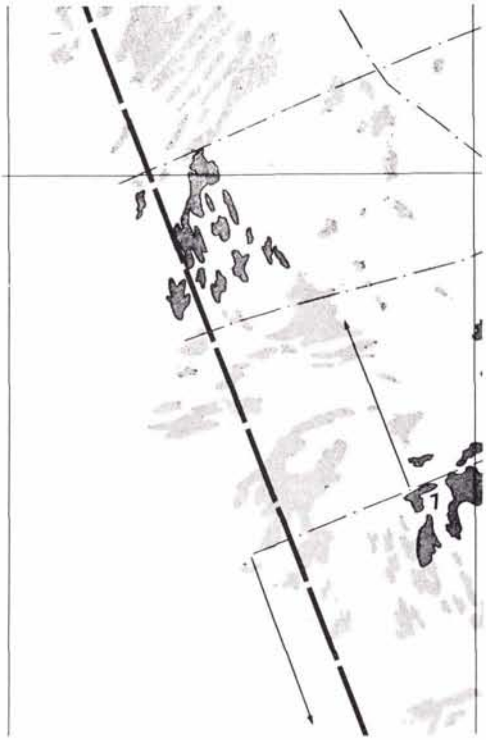


FIG. 4. This small portion of a chart of side-scan sonar imagery incorporates the use of rectified side-scan sonar records with image triangulation. In lieu of mosaicking the records, images of interest were outlined on the rectified records and shown as planimetric features superimposed on special bathymetric charts. This enables the portrayal of the major topography and the minor topography (roughness) as well.

or artifactitious hazard with height are bright red and are classed High Relief Feature—the height of these features with respect to their surrounding is determined and annotated. Medium features are pink. The sonar record of these features indicates height but, because they are marginal, no determination of the height is made. Features with little or no indication of height are brown; the more intense the brown the more intense the sonar image. If the feature shows a sharp boundary, the symbol is outlined with a solid line.

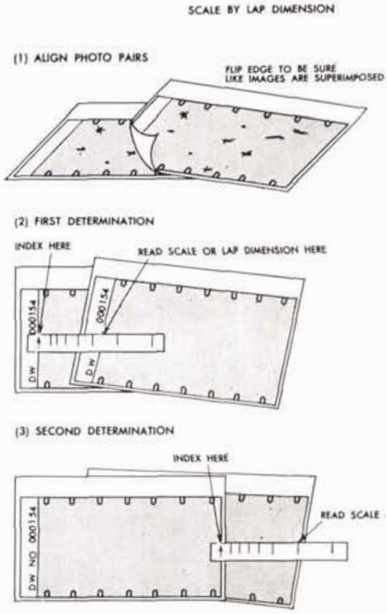
The orthographic delineation of the sonar imagery is achieved by correcting the records for nonuniform scale by photographic stretching of the records to conform with the position fixes (Pollio, 1971). They are then brought to common scale, plotted on the manuscript, and adjusted for residual error.

The major part of residual errors tends to be systematic and indicates both the geometric compression of the side-scan record and the parallactic difference between the side-scan sonar transducers and the positioning system antenna. The difference in position due to parallax varies with speed from about 80 to 100 feet and the error due to geometric compression varies with the depression angle from 0 to about 100 feet (Sanders and Clay, 1968). In both instances the complementary aspect reveals the discrepancy that is then adjusted to about 30 feet, the same accuracy as the position fixes.

The scale of the published chart (1:18,000) negates depicting all the detail observed on the side-scan sonar record (about 1:1,500) and so some generalization in shape as well as in classification is required. The result, however, is a planimetric presentation of the general appearance of the side scan sonar record. Thus, two classes of topography can be shown: the major topography that is greater

FIG. 5. This photograph is one of a series which crosses an isolated outcrop in 1,700 fathoms. The altitude above the center of the photograph is about 13.2 feet. The distance across the photograph is about 12.5 feet. The photograph shows clearly the kind of fauna and topography, and enables positive interpretation of the side-scan sonar.

FIG. 6. Cameras on TELEPROBE are calibrated to yield mensuration data. A scale device based on the parallax principle is used to determine the scale of overlapping photo pairs. Techniques of collimating, lighting and processing have been employed to produce photographs of maximum resolution and clarity for mensuration and interpretation.



than one or two fathoms is shown with contours; the minor topography from a few fathoms to a few inches is shown with roughness symbols.

Comprehensive underwater maps of this kind produced by NAVOCEANO and unique maps of scallop population such as those produced by NMFS are results of the work of TELEPROBE and RUFAS. Remote towed vehicles such as these are numerous and, as the work they do becomes better known and

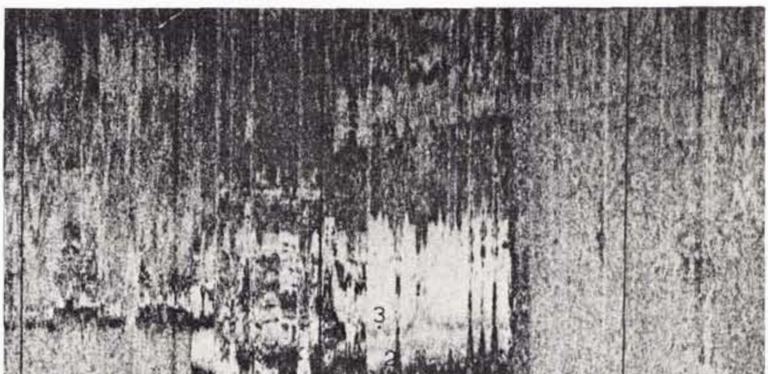


FIG. 7. The starboard side of a 2,500-feet sweep of a side-scan record. The record was obtained at a nominal altitude of 200 feet and represents a horizontal distance of b about 1,250 feet. The sonar images in the center and at the lower right are rock outcrops. The position and height are determined from the imagery and are delineated and annotated on the chart. The photographs of the outcrop, which are keyed to the sonar record, show the nature of the rock and the associated fauna.

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