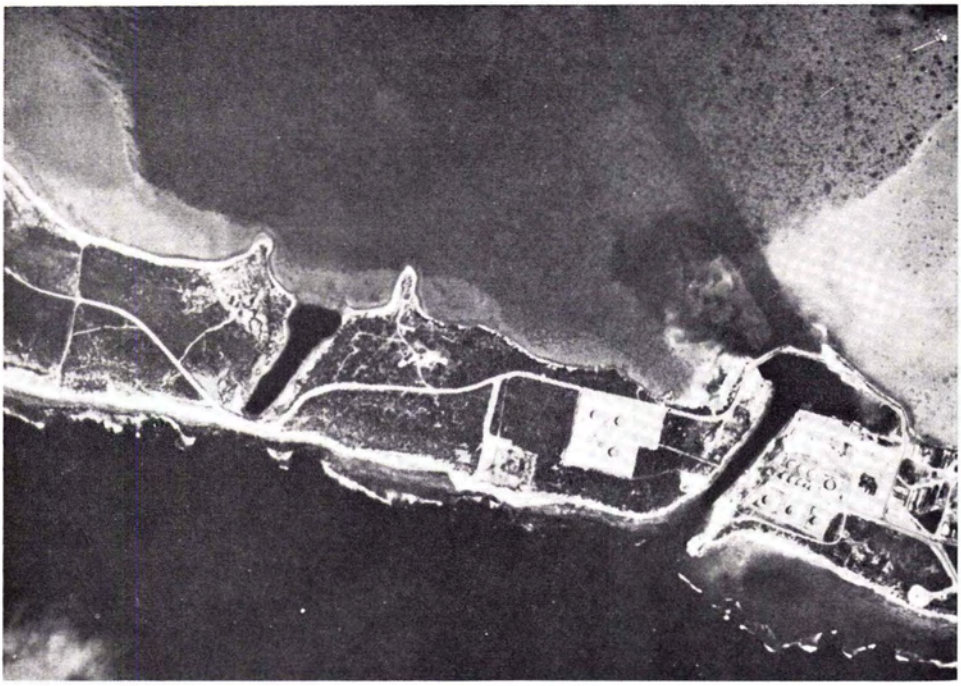

FIG. 1. A black-and-white reproduction of 1:10,000-scale color photograph of Wake Island. The transparencies were cut from the roll of film and inserted between glass for measurement with a Zeiss C-8 Stereoplanigraph.

EDMUND L. GEARY*
U. S. Naval Oceanographic Office
Washington, D. C.

Coastal Hydrography

Color aerial photos, as well as photos from satellites, will aid in charting the world's coasts.

INTRODUCTION

THE OFTEN QUOTED Chinese proverb, "One picture is worth more than 10,000 words," is an understatement of fact when aerial photographs are brought into their true perspective for the purpose of charting coastal hydrography. When military operations and other emergencies dictate their need for a rapid method of verifying the exact location of an island or even its exact shape in connection with its accessibility, a picture is not only worth 10,000 words—it may also be worth 10 times 10,000 dollars. This fact becomes obvious when one takes into account the manpower, equipment, and planning that must be considered before a survey ship is detailed to any area to gather hydrographic data.

Aerial photographs, of course, have many uses. The true extent of their value depends on the user. In the field of hydrography, the use of aerial photographs extends from planning for oceanographic and hydrographic

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survey operations to determining water depths down to as much as 60 feet, depending on water transparency and bottom contrast. With these applications in mind, let us review what U. S. Naval Oceanographic Office personnel are presently doing with aerial photography and what is hoped for in the future.

Aerial Photographs Aid Hydrographic Surveys

The principal objective of hydrographic surveys is to obtain information on water areas and adjacent coastal regions for use as source material in the compilation or revision of nautical charts, sailing directions, and other nautical publications of value to the mariner. The results of the surveys are also used for planning harbor improvements and seaplane anchorages for studies of silting and erosion and oceanographic features, and for military defense projects.[1]

In planning for such surveys, one of the first steps usually taken is to prepare an uncontrolled mosaic from the latest available aerial photographs. Work sheets or planning charts can be prepared showing the location of principal landmarks; general configurations of coast lines, locations of landing beaches and possible camp sites; probable sites for the erection of signals to mark the various stations; and possible tide gage stations installations. More important, the isolated reefs, rocks, and shoals which are visible on the photographs can be located and placed on the work sheets, which greatly facilitates the field survey party's sounding development of the seafloor profile.

Coastal Hydrography from Color Photographs

Experiments conducted with color aerial photography by the U. S. Coast and Geodetic Survey in recent years indicate that color photographs can guide and assist the hydrographer, especially in difficult shallow water areas. Such photographs give him an overall view of the bottom and, therefore, guide his operations and assist him to develop details. It was also pointed out that these photographs could be used to indicate near-shore areas requiring further investigation or more intensive surveys to reveal hidden obstructions as well as for water depth information.[2] U. S. Navy survey ships used color photos for these purposes in the Pacific during World War II.

Abstract: *Aerial photographs have many uses, and the extent of their value depends on the user. In the field of hydrography, the use of aerial photography extends from planning for oceanographic survey operations to determining water depths down to a maximum of 60 feet if water transparency and bottom contrast permit. With these applications in mind, a review is made of actual and potential utilization of aerial photography by the U.S. Naval Oceanographic Office. Color aerial photographs, as well as satellite-taken photography, will play an important role in the development of more rapid and comprehensive methods of charting coastal hydrography. A proposed project to obtain and test color aerial photography of an underwater test range in the Florida Keys should prove invaluable in developing these methods.*

The Oceanographic Office is now attempting to establish that color aerial photographs are an effective and economical means of acquiring data on water depths. A test over a portion of Wake Island was made in 1964 by utilizing selected 1:10,000 scale color transparencies (Figure 1) which were cut from the roll of film and oriented in a first-order instrument (Zeiss C-8 Stereoplanigraph) by

Edmund L. Geary

TABLE 1. RESULTS OF DEPTH READINGS IN STEREO MODELS WITH COLOR TRANSPARENCIES

a. *Model 3 @ 4*	*No. of points read: 127*	
92 points	were within	1 foot
25 points	were within	2 feet
10 points	were within	3 feet
b. *Model 4 @ 5*	*No. of points read: 220*	
166 points	were within	1 foot
46 points	were within	2 feet
6 points	were within	3 feet
2 points	were within	4 feet

inserting the transparencies between plates of clear optical glass. The transparencies were oriented to the same control that governed the construction of the hydrographic survey sheet and the sounding compilation for the area. Stereo-photogrammetric depth readings were made at the locations of the survey soundings over an area of water depths ranging from 0–18 feet. Studies of data shown in Table 1 reveal that: (1) the summary of points concluded a mean square error of ± 1.3 feet; (2) seventy-five percent of all points recorded from the photography were within ± 1.0 foot of the survey depths; and (3), ninety-five percent of all points read were within ± 2 feet of the surveyed depth.

Figure 2 is a portion of the stereo model readout. A comparison with the field sounding data (Figure 3) illustrates the accuracy that was obtained. Using six-inch focal length photography taken at 5,000 feet, the maximum accuracy obtainable with the stereoplanigraph proved to be approximately ± 1.0 foot.

Although the Wake Island test is encouraging as a whole, there is still some doubt as to the accuracy of the depths recorded, both vertically and horizontally. This is largely due to the fact that the photographs were taken with cameras with lenses uncorrected for taking colored photography. Also, there was insufficient information on true depth in the test area.

PHOTOGRAPHY FOR CHART REVISION

Aerial photographs and photogrammetric techniques play an important part in nautical

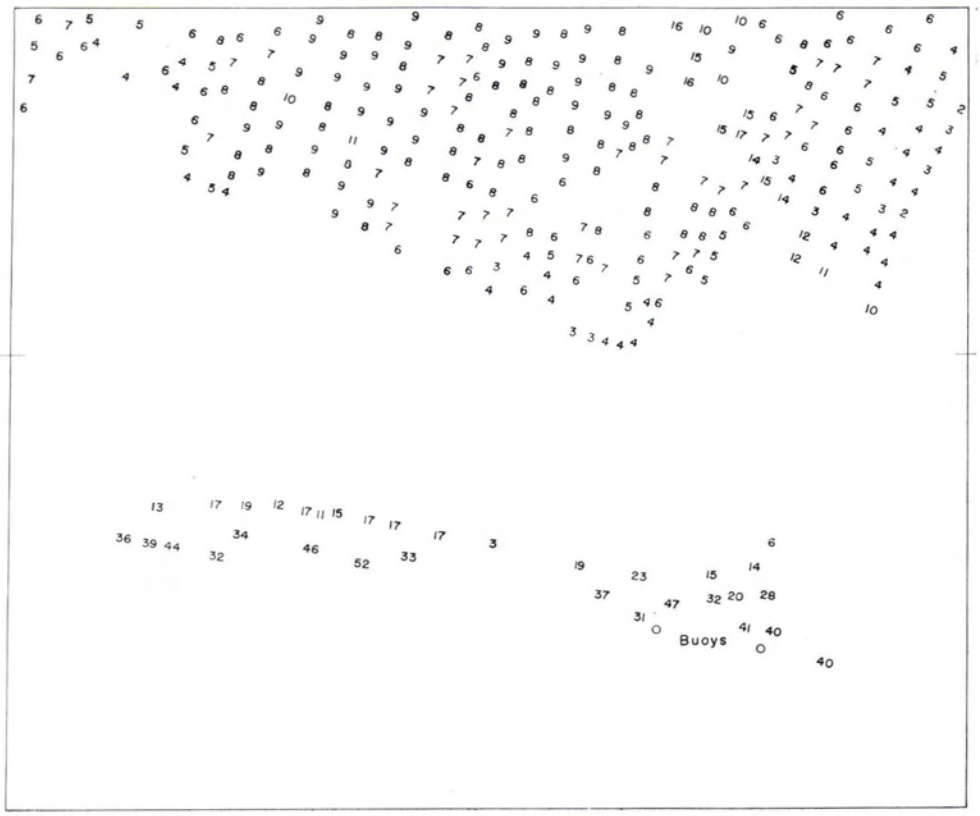

FIG. 2. A portion of the stereo-model readout of the area shown in Figure 1.

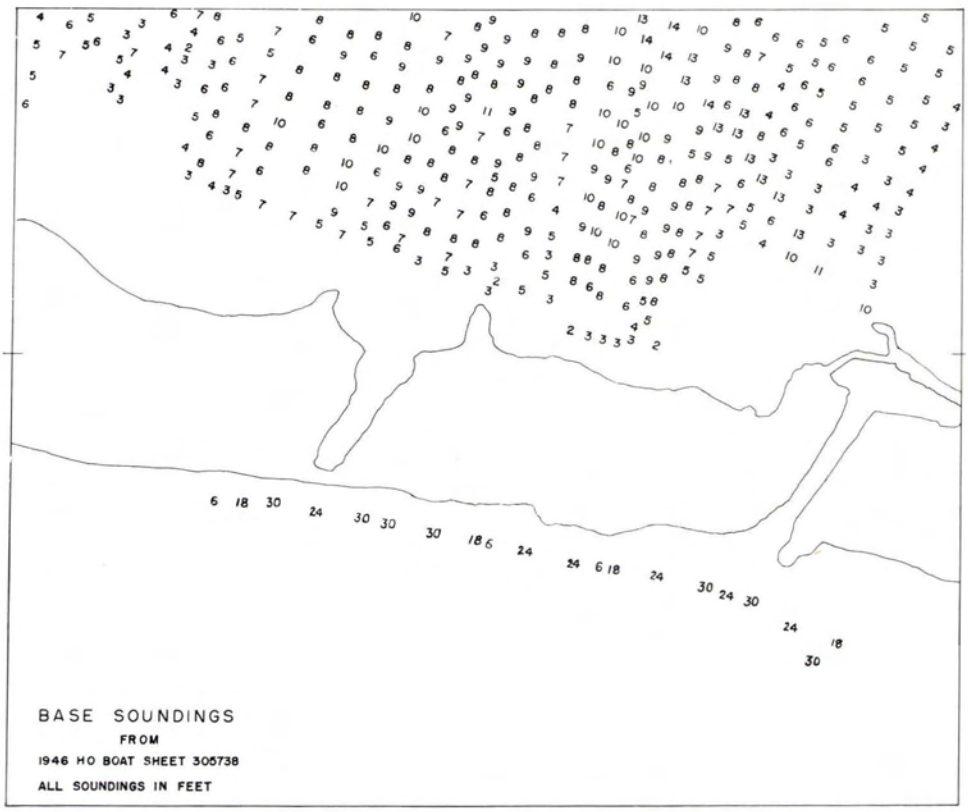

FIG. 3. Field soundings for comparison with the same area shown in Figure 2.

chart revision by revealing changes in ports, port facilities, and coastal areas. For example, a few years ago a portion of H.O. Chart 26-D, showing part of the Bahamas, looked like Figure 4. With the aid of aerial photographs (Figure 5) and photogrammetric techniques, the chart was revised to show shapes and locations of all islands and features as shown in Figure 6. By placing Figure 6 over Figure 4, the errors in the earlier chart become more obvious. The detail of Figure 6 is from a portion of the first edition (11 February 1963) of H.O. Chart 5954, which replaced the seventh edition (June 1943) H.O. Chart 26-D.

The use of space photography for verifying or revising coastal hydrographic detail is a future possibility. If the photographs are also taken in color, more information becomes visible to the photo-interpreter and the photogrammetrist. Figure 7 shows the detail of H.O. Chart 6029 superimposed over a *Gemini-V* photograph. The two atolls are obviously incorrectly depicted on the chart, despite the fact that the chart was compiled from a 1927 Japanese survey. Until recently

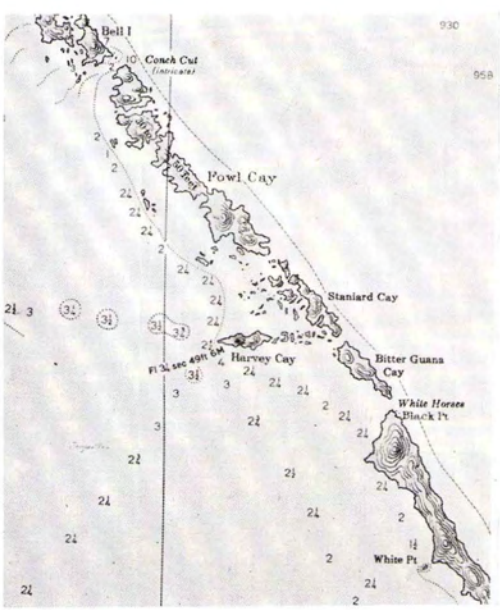

FIG. 4. H.O. Chart 26-D showing part of the Bahamas.

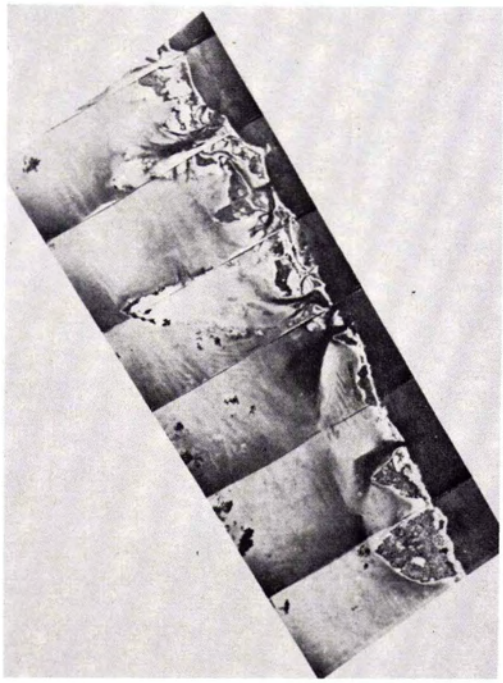

FIG. 5. Photographic mosaic of a portion of the Chart shown in Figure 4.

there was no way, other than a costly ship and land survey operation, by which the information on this chart could be verified or corrected.

Figure 7 shows an enlargement of one frame of the original film taken on the *Gemini-V* space flight in August 1965. Of the photographs taken, only a few were useable for revision of charted detail, due mostly to the non-cartographic type camera and to the presence of scattered clouds. Another reason may be that techniques for spacecraft orientation and photography were still in the experimental stages.

PLANNED DEVELOPMENT

Recently the U. S. Naval Oceanographic Office Research and Development Department initiated a project to obtain color photography over a test range in the Florida Keys. It is proposed to have an array of underwater targets submerged at each 10-foot depth down to 60 feet. All targets in the array can be exposed on one photograph taken from a flying height of 5,000 feet. The flight lines will originate over land and continue in a direction between two exposed reefs. A color target, 100 feet square, will be placed on land and exposed as each flight line begins. At the shoreline, another target will be placed to indicate the water-line (which is often inconspicuous on color photography). The purpose of the large land target is to provide a comparison between the color on the ground target and the submerged targets made of the same materials as the ground target. In order to indicate the water surface and provide reference points for orienting the stereoscopic photos, dye markers of aluminum powder will be placed so that two will appear approximately opposite the center of each photograph.

Concurrently with the photographic exposures, time and "ground truth," consisting of water temperature, salinity, current, and light intensity data will be recorded. This information will later be correlated to the information recorded on the photographs to determine the relationship between depths and color tones; the changes that occur from day to day, or even from hour to hour, as the sun angle changes; and how the water affects the apparent color characteristics of the submerged targets compared to the land target.

The depths of the targets will be known, and the depths of other natural features prominent on the color photographs will be determined. Photographs exposed at altitudes of 2,000, 5,000, 10,000, 20,000, and 30,000 feet will be compared. Selected stereoscopic pairs will be oriented in photogrammetric

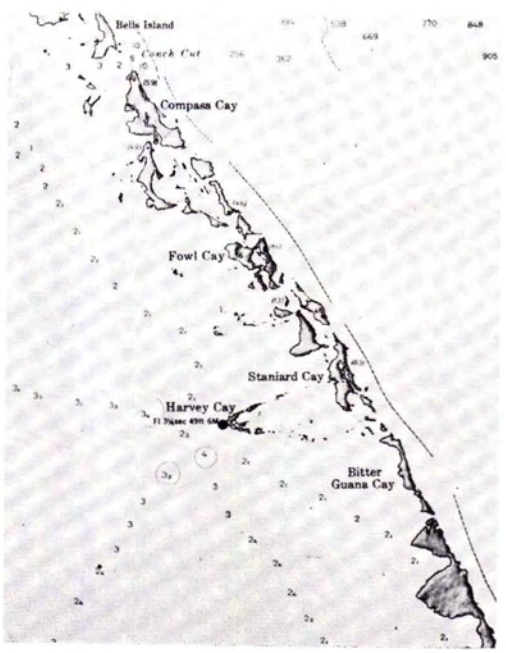

FIG. 6. Revised chart for comparison with Figure 4.

instruments and depths read to compare with the true depths previously recorded. From the information obtained the following can be determined:

- Accuracy of stereo-depth determination from color photography.
- Correlation of photo tones with depths and other physical characteristics of the water.
- Extent of the light filtering effect of water on color at different altitudes.

Photographic Equipment

Realizing the potential of color photography for charting hydrography, early last year the U. S. Naval Oceanographic Office started procurement of color photographic processing equipment. Also, automated color film processing equipment has been obtained by several other Naval organizations. One weak link in the chain still remains; the cameras being used by the photographic squadrons to obtain cartographic color photography are not adapted to obtain optimum color photography. However, this deficiency may be overcome if a new color corrected camera, the KC-6A now under development for another photo system, should become a standard camera in the Navy Photographic Squadrons. The KC-4 camera and the Wild RC-8 cameras will be used in obtaining color photographs over the proposed test range.

Color aerial photography for mapping purposes requires a precision cartographic mapping camera with the highest quality wide-angle color-corrected lens and also a relative aperture of f5.6 or larger. The lens must also provide good and even illumination over the entire focal plane. If not, the star filter or anti-vignetting filter used to eliminate the "hot spot" at the center of the photography will be so dense that there will be too little light for good exposure of the film. In color photography, the filter must also cut out the ultra-violet and part of the blue light.

Other Factors

Assuming that equipment requirements are met, other factors such as water transparency, bottom contrast, tide conditions, and sun spots remain as variables. Of all such factors affecting quality and useability of color aerial photography, water transparency is the least known. Sun spots and tide, on the other hand, can be predicted from known data. Therefore, in the final analysis, the ability to determine water depth will become primarily dependent on water trans-

FIG. 7. Detail of H.O. Chart 6029 superimposed over *Gemini-V* space photograph.

parency and bottom contrast. Water transparency will vary from 8 to 10 feet in Alaska to 60 and even 70 feet over a clean coral bottom as in certain parts of the Caribbean.[3]

Conclusion

Color photography will provide a means for more rapid acquisition of depth information for near-shore areas, and the information obtained on the previously mentioned test will be invaluable in developing this method. Continuing use of aerial photographs, particularly satellite photography, can provide rapid acquisition of data over remote areas of special significance. The use of satellite photography can vary from chart revision to the study of disasters caused either by man or nature. Its applications are unlimited. Future developments will dictate to what extent this type of photography will be used. Until then, conventional aerial photographs will have to provide all the necessary information.

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Forum

Dear Sirs:

Enclosed is my check to cover the following: annual dues, Selected Papers on Remote Sensing, and silver pin.

Since my return from Vietnam, I have no difficulties with neither receipt of the magazine nor any other correspondence.

Personally, I would like to see more articles reference the interpretation of photography. Like possibly several others, I am new to the field and my mathematics is also not up to the level required for a fuller understanding of some of the more rarified items of interest.

I am indeed amazed at the sophistication of much computerized equipment and am sure that it all serves a most useful purpose; however, without personnel highly trained to permit the utmost use of the equipment, it would seem somewhat superfluous. I gather the impression that the highly sophisticated equipment might possibly interfere with view of the woods due to the obstruction of the tree line.

I do, however, thoroughly enjoy and find very interesting the articles that I am technically able to understand.

—William S. Barker
Knightstown, Indiana