MODERN NAVIGATION
A CHALLENGE TO CARTOGRAPHERS

An Estimate of the Effects on Charts of Recent Navigational Developments, Particularly Radar, as Related to Topography and its Portrayal

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From the viewpoint of the chart-maker, a combined session of the Cartographic and Topographic Divisions of this Congress is very much in order, for a chart is built upon the labors of both cartographers and topographers. Their dual contributions have become more important than ever, now that we are trying to produce charts that will enable the navigator to take full advantage of the advances of modern navigation.

In the light of some of these developments it way be helpful to look at the charting situation from the standpoint of user requirements of modern navigators. How much has the introduction of electronics and particularly radar altered the need of the navigator to know the shape of the land about him, to have the topography clearly portrayed on his chart?

As you know, the radio aids to navigation developed during the last generation - loran, radio direction finding, omni-range, and so on - are sometimes described as having simplified the navigator's work so much that it is becoming less important to chart the features of the land. This is of course an extreme view, and we find from the navigators themselves that they still have to be able to recognize the earth's features when they are visible. Nearly as important, they must have have a good mind's eye view of them when they are not visible.

The navigator has always needed to know the topography of the land about him. Supplemented by one or another aid to navigation, the land surface itself provides the basic, unchanging navigational information: the hills, the valleys, and the coasts; the mountains to be cleared and the reefs to be avoided. Whatever the aid to navigation used, its purpose is to locate the navigator in relation to the land - to guide him around its hazards, and to bring him to the haven of airfield or harbor.

The portrayal of this basic topographic information, together with the supplemental aids to navigation, imposes a most exacting task on the chart-maker. He must design his chart for use by an airman flying at a clip of several hundred knots, or for a mariner approaching an unfamiliar coast. A navigator in such circumstances has too many other problems to be able to stop for interpretation of a poorly designed chart. Nor can he hesitate while trying to identify the land about him from inaccurate topographic information on his chart.

This need for quick comprehension of the topography about his ship or plane applies especially to the radar navigator, for the topographic features themselves are the major radar targets, shown in light and shadow on the radar screen for the navigator to interpret. Because a great deal is being said these days about the pro-

blems of radar interpretation, it is well to reassure ourselves that the operation of radar is not at all difficult to understand.

A radar set shows on its screen a picture of the land surfaces which would be lighted if the radar were replaced with a brilliant flare or bonfire. Put this radar bonfire on the mast-top of a ship in a harbor at night, if you will. Now a pilot looking down from a plane overhead will see a light-and-shadow display very much like the picture of the ship's radar screen. Because of its plan view arrangement, this type of radar screen is called a Plan Position Indicator, or PPI.

The PPI aboard our ship shows patches of light all along the shoreline of the coast where it is bold, and it shows other patches from the inshore hill and mountain slopes facing the ship. Shadow areas appear behind the hills. Along the low and swampy stretches of the coast, there are areas only dimly lighted on the PPI.

The PPI on the plane flying above the ship shows much the same picture from its own radar, except that the shadow areas would be smaller and the hills close under the plane might have no shadows at all. In the cases of both the ship and aircraft radars, the chief difference between the appearance of the radar screen and that of the light-and-shadow picture from the imaginary bonfire is that neighboring spots of light on the radar screen merge into each other, being generalized and spread in short arcs concentric to the center of the screen.

The significant thing to the chart-maker about all this is that radar sets do not respond to some new species of electronic feature in the landscape. They are responsive to most of the same major topographic and cultural features that are customarily shown on nautical and aeronautical charts designed with no thought of radar. Consequently, the chart-maker who has the radar navigator in mind must still show these features of the land, or at least their radar equivalents.

This particular possibility, that perhaps there may indeed be some way of showing the radar equivalent of topography, has interested chart-makers and navigators alike since radar was first introduced. The interest of the chart-maker, it might be said, is mingled with considerable alarm at the prospect of having to turn out duplicate series of charts, one for ordinary navigation and one for radar use. It is bad enough that we have to maintain duplicate sets of aeronautical charts for areas where loran is available, to avoid having to print the complex loran patterns on the same chart with other visual and radio aids to navigation. But even if the Hydrographic Office is resigned to the twin series of charts made necessary by loran, it reacts strongly to talk of triplets. A third addition to the family, an aeronautical chart intended only for radar navigation, is not wanted. And in the world family of nautical charts, of which the Hydrographic Office now supports some 5600 members, there is no sentiment at all in favor of adopting another series for radar use.

Despite this reluctance to think about putting out special radar charts on a wholesale basis, the charting agencies have produced a number of experimental charts designed to assist in radar navigation. The Aeronautical Chart and Information Service printed a series of Radar Charts, The R.C. Series, in 1946, which show relief-shaded topography with spot elevations and no contours. These charts cover the United States at a scale of 1 : 1,000,000.

For the mariner, the Coast and Geodetic Survey has issued special charts showing relief by contours and hypsometric tints. These charts are useful for normal navigation, but were designed with the hope that the bands of different colors might serve as successively higher radar coast lines for ships too far at sea to pick up the actual coast line at the water's edge.

For radar piloting in rivers, the Corps of Engineers has produced charts that might seem to be the obvious answer to all radar navigation problems ; charts using mosaics made from actual photographs of radar screens. These mosaics are arranged either as separate charts or as overprints in fluorescent ink on standard charts. These mosaics have proven useful for piloting in narrow passages where all vessels must take the same course followed by the survey vessel. But their value is questionable for radar navigation along an ocean coast, where there is the difficulty that the radar picture changes so markedly with increasing distances offshore.

Using another approach, the Hydrographic Office printed a series of Radar Piloting Charts in 1945. These charts covered the approaches to important harbors in the United States and elsewhere. They showed coastlines, tops of peaks, ridge lines, and built-up areas of cities. The navigator located himself on them by use of the VPR, or Virtual PPI Reflectoscope. Because we are beginning to hear of the VPR again, it is worth describing briefly and explaining its relation to radar charting.

The VPR allows the navigator to look directly at the radar screen and see the reflected image of his chart superimposed upon it. The chart image is reflected in just the same way the protective glass of a television screen reflects the images of table and floor lamps in front of it. If this glass front were to be tilted forward, it would reflect the image of a lighted chart held flat before it. Used with a radar screen, this arrangement lets the navigator move his chart features on his chart. His own location can then be marked on the chart at the center bright spot of the radar screen.

The VPR method worked very well in practice, but matching a chart to the picture on a radar screen has one serious drawback. Radar screens come in a number of sizes and each radar set can be switched to show four or five different ranges. The number of natural scales produced by these various combinations has made it out of the question to produce charts to match all or even some of them.

But now suppose that the radar designers could turn out a radar screen with a scale that could be adjusted to match that of any chart. With such equipment, the navigator could use the charts at hand to pin-point his position. As his ship or plane moved, he could plot positions as often as it pleased him, simply by shifting his chart to keep up with the moving returns on his radar screen.

It is encouraging to learn that radar designers have now come forth with just such a variable-scale radar screen, at least for shipboard use. No such equipment has yet appeared commercially in this country, but an experimental version has already been tested and described by the British. However, as important as it is, such a radar screen cannot solve the problem of marine radar navigation overnight. The mariner will still find himself in situations where it is difficult to match radar returns to the land features as shown on the usual nautical chart.

Unless he is close to shore and the coast rises sharply, his radar will not pick up the shoreline shown on the chart. Instead, it will show a hodge-podge of returns from inshore features which may not even be charted. Even if he is near a well-surveyed coast, his chart may show topography at an unsatisfactory contour interval for radar use. Just where the coast itself is low and not much help for radar navigation, the inshore features also are likely to be low and poorly defined by contours. Even where the topography is shown adequately by contouring, the navigator using the VPR may have trouble looking simultaneously at chart and radar screen and trying to make out the land relief, the hill and mountain masses which are the targets for his radar.

There are two phases of the chart-maker's remedy for this situation. He must have the cartographer present the relief in such a way that the land forms can be comprehended at a glance. And, along many coasts that are low and have no bold relief, he must have more topographic information than has yet been surveyed.

Obtaining the topographic information is a matter of budgets and emphasis. The navigator using the VPR and variable-scale radar screen will soon enough remind us of these areas where more topographic information should be shown. As for better ways of presenting relief, no cartographer needs to be reminded of the advances that have been made in this field. Our own and European cartographers, in both government and commercial practise, have made very real progress in showing relief by coloring and shading.

These techniques for showing relief appear immediately adaptable for charts to be used for radar navigation, and they may be welcomed for ordinary methods of navigation as well. Other methods such as the physiographic diagram also merit investigation and should not be overlooked. Although these methods are

promising, it is possible that any technique requiring special coloring to help portray relief on charts may not be practicable, because the colors of radar screen phosphors may interfere with the intended cartographic effect. Special colors can also be undesirable for viewing under red light. One-color shading in grey or brown appears a reasonably satisfactory method for showing relief and this procedure is now being followed by the Hydrographic Office on its nautical charts.

Relief shading of topography is applicable as well to aeronautical charts, and the Hydrographic Office is also experimenting along this direction at present. However, because no airborne radar with a variable-scale screen has been announced, it may be considerable time before suitable tests of relief-shaded aeronautical charts can be made to find their utility in radar navigation.

For the present, it remains apparent that topography still provides the basic navigational information about the land. It is needed alike for marine and air navigation, and by traditional as well as by modern methods of navigation. Having reaffirmed this importance of topographic information, the chart-maker may hope to arrive at better methods of portraying it, in order to produce charts that enable the navigator to make still better use of the new navigational tools now available to him.