CHAPTER 11

MANEUVERING BOARD

LEARNING OBJECTIVES

After you finish this chapter , you should be able to do the following:

1. Define the basic terminology associated with and explain the layout of the maneuvering board.
2. Solve basic relative motion problems, stationing problems, avoiding course problems, and wind problems.

INTRODUCTION

In CIC, Operations Specialists use a variety of devices—radar, radar repeaters, NTDS consoles, DRT, surface plot, and maneuvering board—to obtain information (course, speed, closest point of approach (CPA), etc.) on all surface contacts within range.

The maneuvering board is used to determine the relative motion between own ship and a contact. Since relative motion is important to the safety of own ship, Operations Specialists must be able to solve every type of maneuvering board problem related to every type of evolution. This chapter deals with a variety of maneuvering board problems, beginning with the very basic information and moving up to more advanced problems.

RELATIVE MOTION

The solution to any maneuvering board problem is fairly simple if you understand the fundamentals of relative motion.

Motion is change of position. All motion is considered relative to some frame of reference. There are two types of references: fixed and moving. A common fixed frame of reference is the Earth. A change of position in relation to the Earth is called *geographical* or *true* motion. An automobile traveling from Baltimore to Philadelphia and a ship steaming from San Francisco to San Diego both exhibit true motion. In both examples the vehicle is moving from one point on the surface of the Earth to another.

The motion of *one object with respect to another object* is called *relative* motion. In relative motion, only the motion (both direction and speed) between the two objects is considered. This means that one of the objects is considered to be at rest *within their frame of reference*. For example, consider two vehicles traveling in the same direction on a highway. Vehicle A has a speed of 65 miles per hour. Vehicle B has a speed of 75 miles per hour. A police officer standing at the side of the highway and checking the speeds of the vehicles with radar would record 65 miles per hour for vehicle A and 75 miles per hour for vehicle B—relative to the Earth. These are the vehicles' *true* speeds. Now assume that you are driving vehicle A. As vehicle B passes you, since it is travelling 10 miles per hour faster than your vehicle, it moves away at a *relative* speed of 10 miles per hour. You have the same sensation of speed between your vehicle and vehicle B that you would have if your vehicle were parked and vehicle B passed you at a *true* speed of 10 miles per hour. When you deal with relative motion, remember that only the motion between the two vehicles matters.

As an Operations Specialist, you must be able to visualize relative motion, because the sweep origin of a PPI scope (own ship's position) is fixed. Thus, the motion you see on the PPI scope when own ship is in motion is relative motion. (You will see true motion on a PPI only when own ship is stationary or when the presentation has an input from the dead-reckoning analyzer.)

A simple CIC problem that emphasizes relative motion is one having two ships on the same course, as shown in figure 11-1. Ship A is on course 270° and making 25 knots. Ship B is 1,000 yards astern making 10 knots and also steering 270°. It is obvious that the range between these two ships will increase as ship A

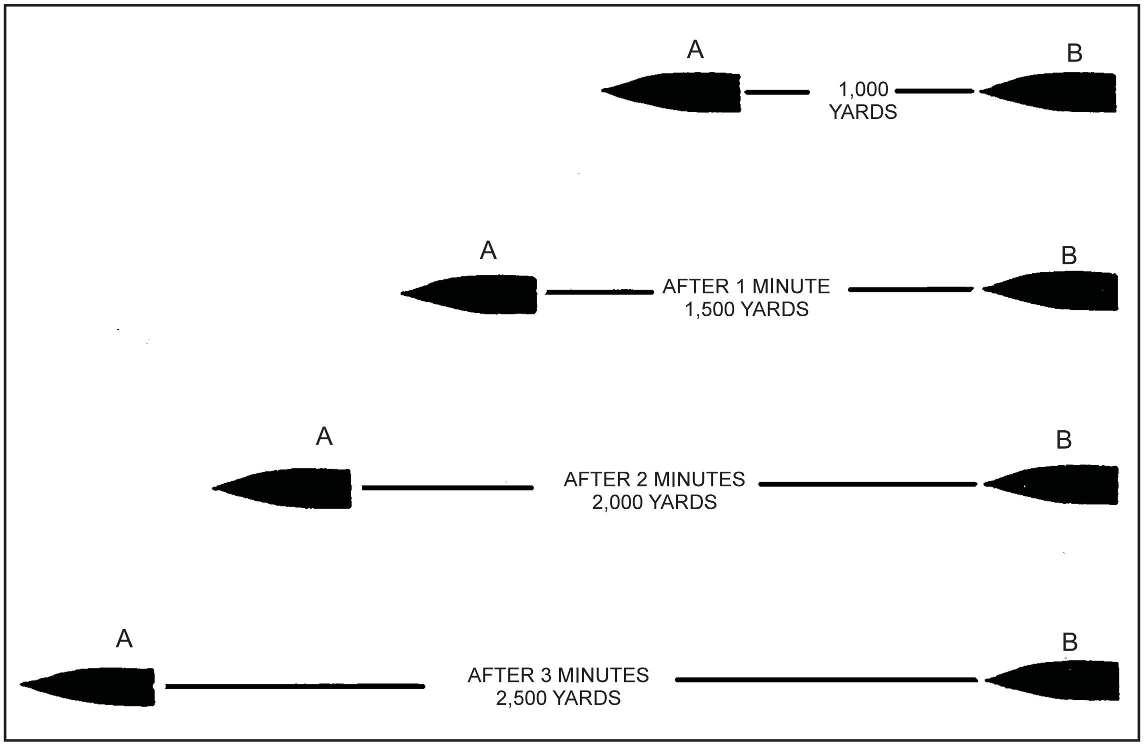

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Figure 11-1.—Relative motion of ship A in relation to ship B. Ship A speed 25 knots. Ship B speed 10 kts.

moves away from ship B. The opening speed is 15 knots, the difference in the speeds of the two ships. Ship A is, then, traveling at a speed of 15 knots, *with relation* to ship B. Relative motion, then, is not concerned with ship A alone or ship B alone, but with the relationship of ship A to ship B.

An observer aboard one ship must judge movement by relating it to that ship. In this example, think about relative motion from the point of view of an observer on ship B. Concentrate on what is happening to the relationship between the two ships—that is, what is happening to the bearing and range of ship A from ship B.

As observed on the PPI scope, A's bearing is always the same (270°), but range is opening constantly at a rate of 15 knots or 500 yards per minute. Stated more precisely, the direction of relative motion is 270° and speed of relative motion (SRM) is 15 knots. Although ship A has a true speed of 25 knots, it is making only 15 knots in relation to ship B.

Now let's consider a situation with two ships on different courses and speeds. Two ships get underway from the same anchorage at the same time (fig. 11-2); ship C is on course 180°, speed 15 knots; and ship D is on course 090°, speed 20 knots.

If you were the surface search radar operator aboard ship C, you would observe ship D moving out from the center of the scope, in a northeasterly direction. See figure 11-3. After an hour, with the ships maintaining their original courses and speeds, ship D would be located at 053°, 25 nautical miles from ship C.

The speed of relative motion (SRM) between these two ships then, must be 25 knots; and the direction of relative motion (DRM), in relation to ship C, is 053°.

You can figure the solutions to these simple problems in your head. However, most relative motion problems are more complicated and require you to use a maneuvering board.

Q1. What is the definition of relative motion?

THE MANEUVERING BOARD

The maneuvering board is a polar-coordinate plotting sheet devised to solve relative motion problems. See figure 11-4. It contains ten equally spaced circles and thirty-six radial bearing lines, one every 10°, originating at the center. At the bottom is a nomogram, which is used to compute speed, distance, and time. On each side of the sheet are two vertical scales, known as *speed/distance scales*.

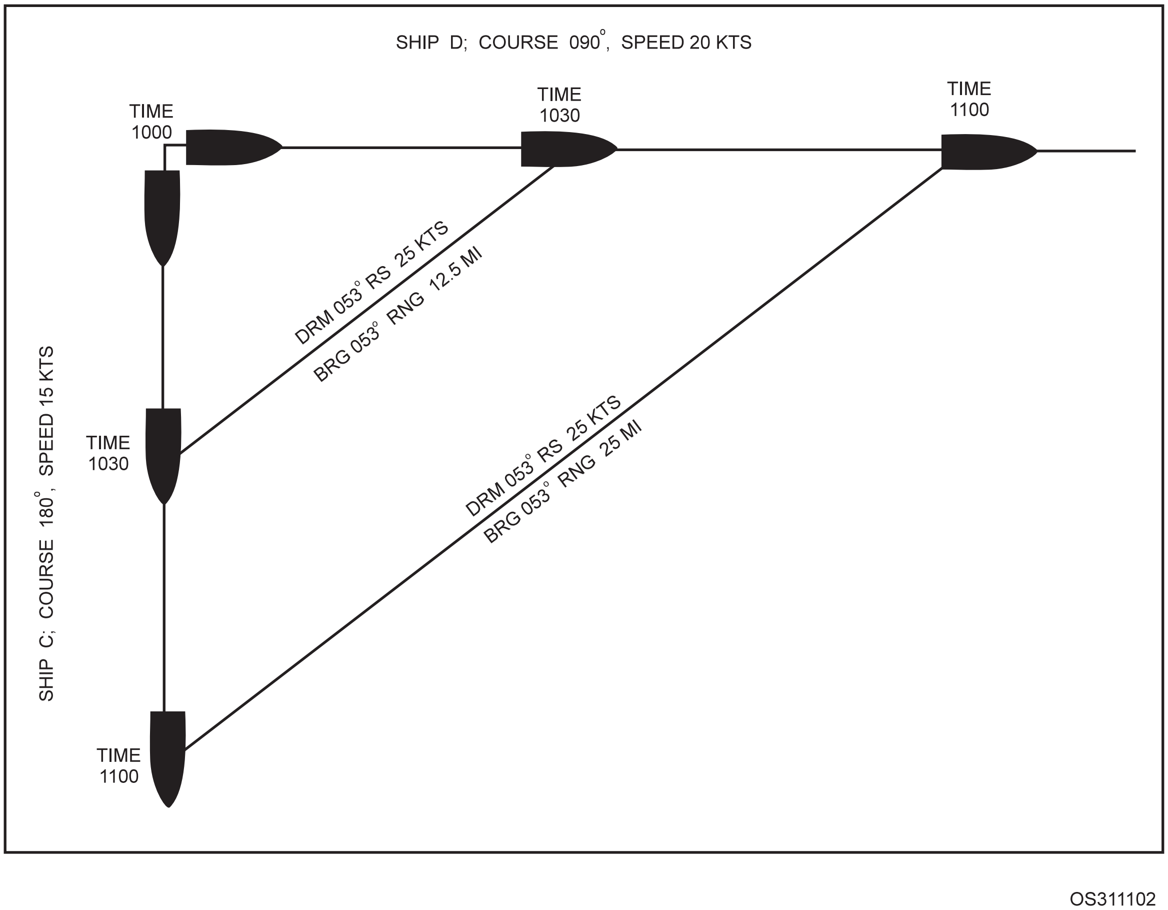

Figure 11-2.—Relative motion between two ships.

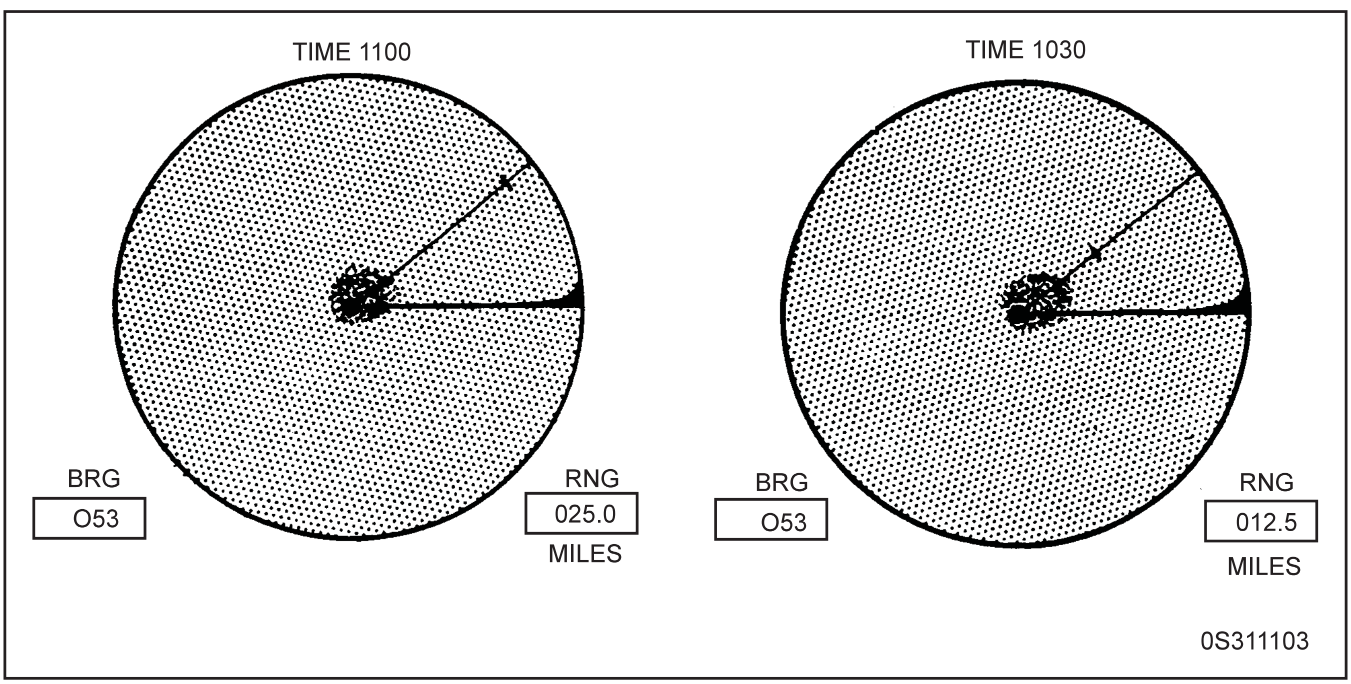

Figure 11-3.—PPI presentation observed on ship C.

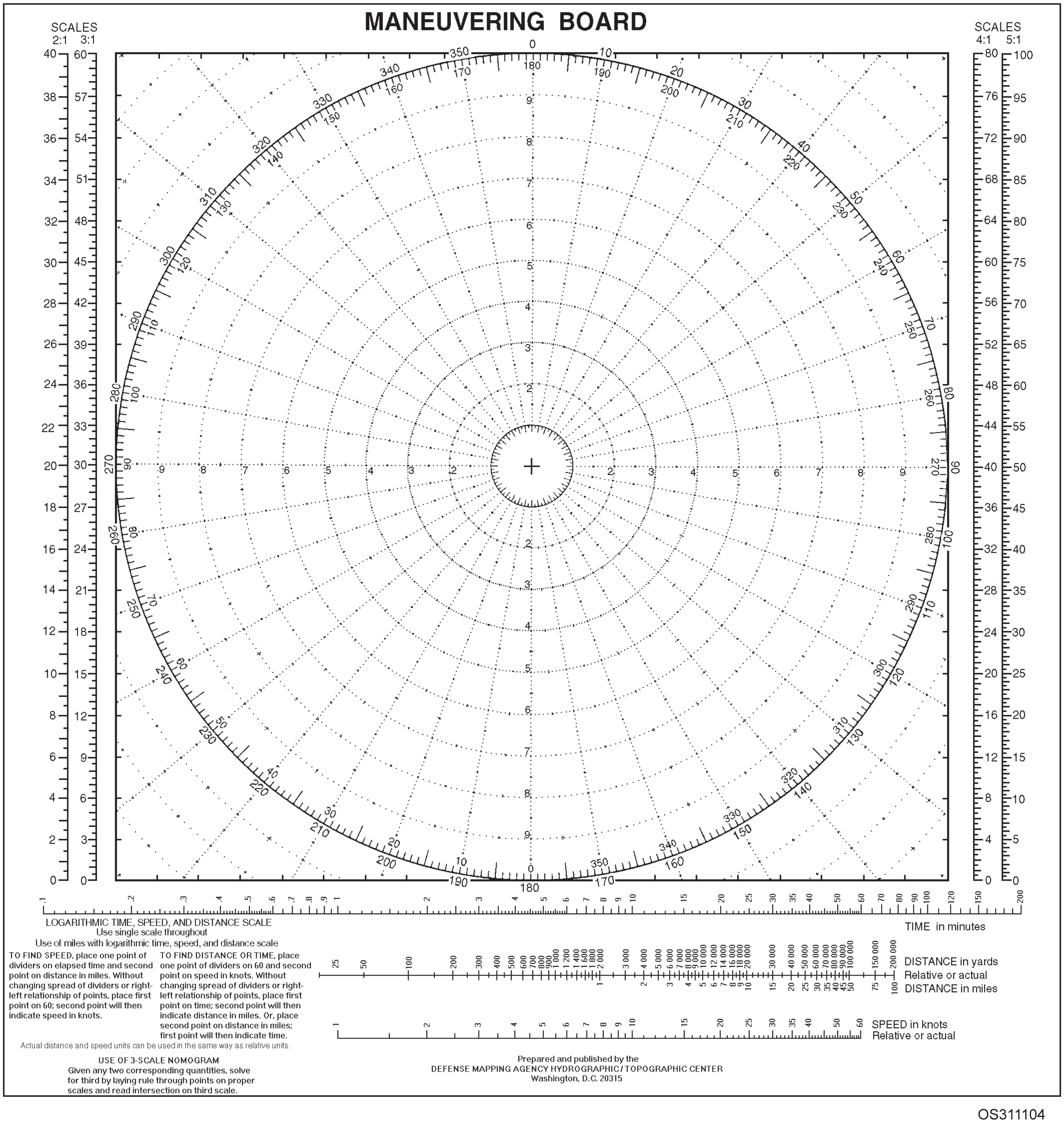

Figure 11-4.—Maneuvering board.

To work maneuvering board problems, you need two additional pieces of equipment:

1. Dividers, for accurate measurements of time, distance, and speed
2. Parallel rulers, to accurately parallel lines of motion

Before you begin working maneuvering board problems, you must understand vectors and the vector diagram as they are used in maneuvering board problems.

VECTORS

We often use the terms *speed* and *velocity* interchangeably, and sometimes we are justified in doing so. However, speed is not always the same thing as velocity. Strictly speaking, speed measures the rate of travel, while velocity involves not only speed but also direction. Velocity then, is the time rate of motion in a specified direction.

Velocity can be expressed in the form of a vector. A vector is a quantity having both magnitude and direction and is represented graphically by an arrow. In maneuvering board problems, the direction of the vector arrow is used to indicate a ship's course. The length of this same arrow is used to represent the ship's speed. As you plot two or more vectors during a maneuvering board problem, you will be performing a process called "vector addition and subtraction". This process can become somewhat involved, so rather than explain the concept of vector addition and subtraction in detail, we will simply teach you how to plot the vectors and interpret the results. The important point for you to remember is to plot your vectors very carefully, so your results will be accurate.

RELATIVE PLOT

In solving any relative movement problem on a maneuvering board, you must assume one of the moving ships to remain at the center of the relative plot. Therefore, your first consideration is which of the moving ships to place in the center. This ship can be either own ship or another ship upon which ranges and bearings are being taken.

There are advantages to plotting own ship in the center. For example, placing own ship in the center shows the same picture as the one shown on a PPI scope, and any errors in the solution are readily apparent on the scope.

In certain types of problems, such as change-of-station problems, you may find it more convenient to place the formation guide in the center of the maneuvering board.

Regardless of the method you use, refer to the ship you place in the center of the maneuvering board as the reference ship and label it R. Refer to the ship whose movements are being considered in relation to the reference ship as the maneuvering ship and label it M. At the start of a maneuver label the position of M as "M_1" Label its plotted position at the end of the maneuver as "M_2". When you need to plot more than two positions of the maneuvering ship to solve a problem, label them M_1, M_2 , M_3, etc., in consecutive order.

The direction of the line joining the plots from M to M represents the direction in which the maneuvering ship (M) is moving with respect to the reference ship (R). See figure 11-5. This direction is called the Direction of Relative Motion (DRM) and is expressed as a true bearing. Remember, this is not a true movement, but rather the relative movement, which is the result of combining the reference ship's course and speed and the maneuvering ship's course and speed, making the maneuvering ship travel down the DRM line.

The distance between the positions M_1 and M_2, measured to the same scale used to plot M_1 and M_2, is the distance M traveled with respect to R. This is called relative distance. Again, remember that this is not a true distance; it is the relative distance, which is the result of the reference ship's course and speed and the maneuvering ship's course and speed. Relative distance, then, is the measurement of the distance between M_1 and M_2. Be sure to use the same scale for this measurement as you used to plot M_1 M_2. After you determine the distance between M_1 and M_2 and the time between the plots, you can determine M's *relative* speed. Relative speed is the speed at which the maneuvering ship is moving in relation to the reference ship.

You can solve for relative speed by using the nomogram at the bottom of the maneuvering board. In fact, if you know any two of time, distance, and speed, you can quickly determine the third by using either the nomogram or the logarithmic scale. We will explain how to use the nomogram and the logarithmic scale later in this chapter.

Now, consider the following definitions. You will use them whenever you solve a maneuvering board problem:

1. *Direction of relative motion (DRM)* — This is the direction the maneuvering ship (M) moves in relation to the reference ship (R).
2. *Relative distance (RD)* — This is the distance the maneuvering ship moves with respect to the reference ship in a given period of time.
3. *Speed of relative motion (SRM)* — This is the speed at which the maneuvering ship moves in relation to the reference ship.
4. *Line of relative motion (LRM)* — This is the line that starts at M_1 and extends through M_2 , M_3, and so forth.

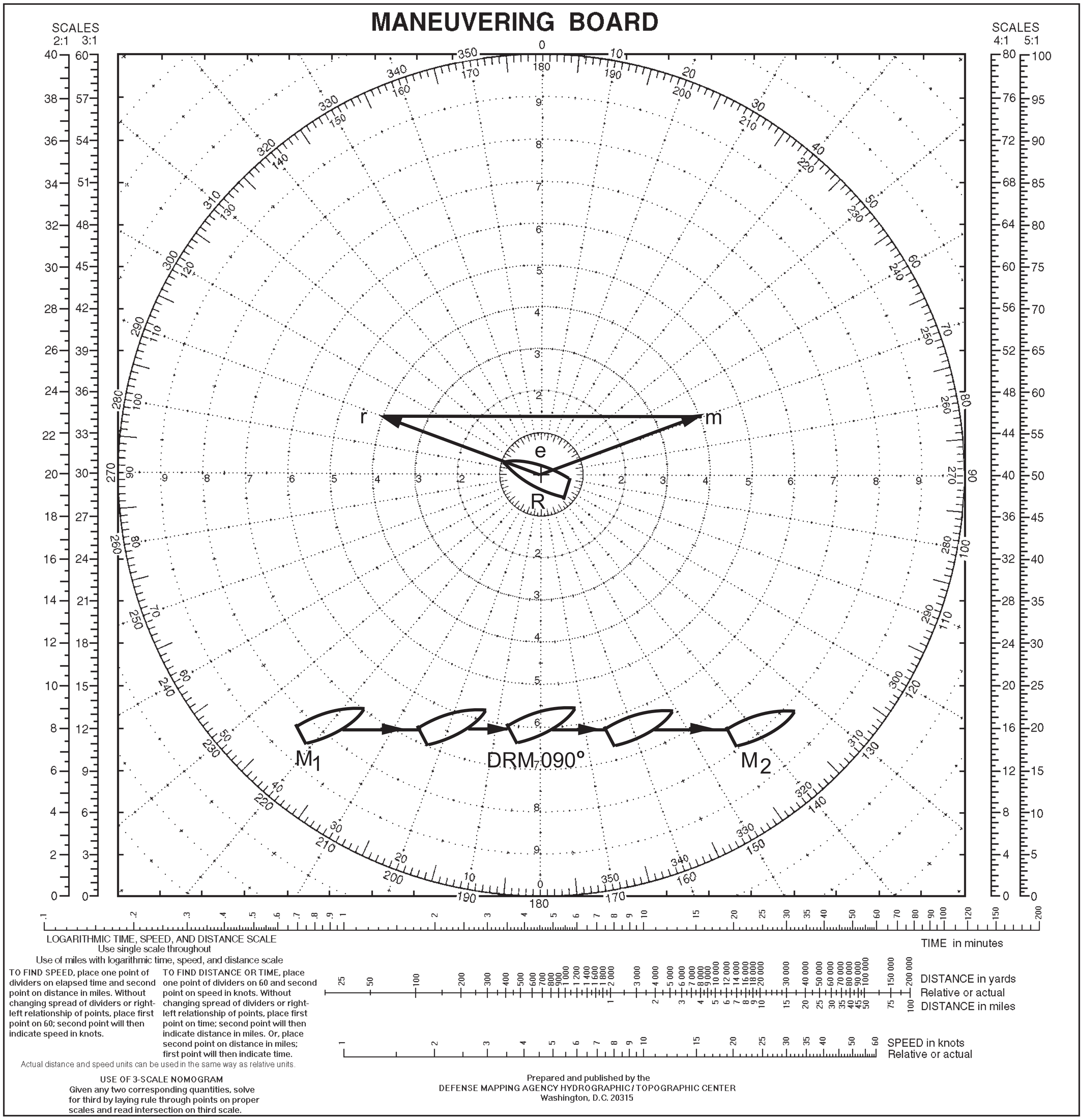

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Figure 11-5.—Relative motion of M with respect to R.

VECTOR DIAGRAM

The true course and speed of each ship is represented on the maneuvering board by a vector drawn outward from the center. The direction of each line corresponds to the course of the ship it represents, while the length of each line corresponds to the ship's speed, plotted on some convenient scale. Standard labels for vectors are used in all maneuvering board problems. Figure 11-5 shows the basic vectors and their labels. The vector *er* represents the true course and speed of the reference ship. The vector *em* represents the course and speed of the maneuvering ship. The vector *rm* represents the relative course and speed of M with respect to R

Relative vectors, such as the *rm* vector, originate outside the center of the maneuvering board. Thus, in maneuvering board problems, true vectors always originate at the center, and relative vectors always originate outside the center.

Note that since the $M_1 M_2$ vector and the *rm* vector both indicate direction of relative motion, $M_1 M_2$ and *rm* must be parallel and, in every case, drawn in the same direction.

NOTE

To complete the following maneuvering board problems, you must have a few maneuvering board sheets, a set of dividers, parallel rulers, and a pencil. We will explain the mechanics as we proceed through the problems.

HOW TO USE THE MANEUVERING BOARD SCALES

The maneuvering board contains three types of scales: bearing scales, speed/distance scales, and the nomogram. The bearing scale consists of two sets of numbers printed along the maneuvering board's outer circle. The large, outer numbers are true bearings; the small, inner numbers are reciprocal bearings. For example, the reciprocal of 030° is 210°.

The speed/distance scales are provided for you to use when you need to expand the scale of the maneuvering board. The basic circular area of the maneuvering board is based on a 1:1 scale, with the outer circle representing a distance of 10,000 yards. If you need to plot a distance greater than 10,000 yards, use the appropriate time/distance scale to take your distance measurements and expand the distance to the outer ring according to the speed/distance scale you use. For example, if you use the 2:1 scale, convert the outer circle to 20,000 yards (10,000 multiplied by 2). If you use the 5:1 scale, convert the outer circle to 50,000 yards. By expanding the overall scale, you can have the distance between circles on the maneuvering board represent 1,000, 2,000, 3,000, 4,000, or 5,000 yards.

You can also use the speed/distance scales to measure speeds in the vector diagram. On the basic plot, the outer circle represents 10 knots, with each circle representing 1 knot. When you use speed/distance scales, the outer circle represents 20, 30, 40, or 50 knots; with each circle representing 2, 3, 4, or 5 knots (depending on which scale you chose).

The surface search radar will often detect more than one contact at any given time. You can't expect all of these targets to be the same distance from your ship or to have the same speed. To plot this variety of targets, you might be tempted to use a different maneuvering board for each contact. An acceptable alternate to using several maneuvering boards is to do all contact solutions on the same board, using a 5:1 scale for both distance and speed. This scale is compatible with the maximum speed of most ships and with the range scale used by the surface search operator. During tactical maneuvers and other times when greater accuracy is needed, you may select the scale that fits the specific problem.

You may also find it convenient to choose one scale for the relative plot (distances) and another for the vector diagram (speeds). We will discuss how to do this later in the chapter.

At the bottom of the maneuvering board is a nomogram (a set of three interrelated scales). The nomogram provides you a quick way to convert time and speed to distance, time and distance to speed, and speed and distance to time.

Figure 11-6 illustrates time-speed-distance scales. All three scales are logarithmic scales. The top line is a time line, in minutes. The middle line is the distance scale (numbers on top of the distance scale give distance in yards; those below, distance in miles). The bottom line is the speed scale, in knots.

In our discussions concerning the speed and distance scales, we use the words *relative* and *actual.* We do this only to inform you that you may solve both

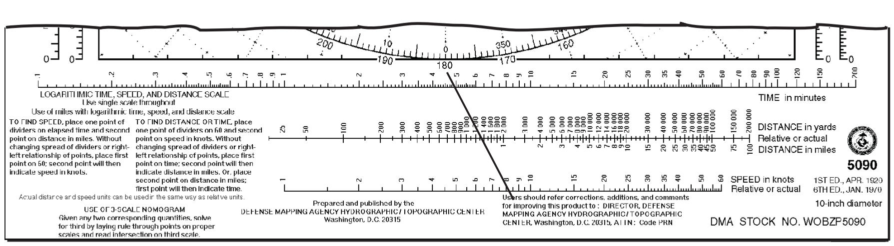

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Figure 11-6.—Maneuvering board nomogram.

relative and actual problems. When you solve a problem, be sure to use the same type of speed and distance. For example, if you use relative distance, be sure to use relative speed.

Time-speed-distance scales are based on the formula "Distance = Speed x Time". They are so arranged that by marking off any two known values and laying a straightedge through the two points, you can determine the correct value of the third quantity, which is the point of intersection on the third scale.

Suppose a ship travels 1500 yards in 5 minutes. What is the speed? Figure 11-6 shows the graphic solution to the problem. Time is marked at 5 minutes on the time scale. Distance is marked at 1500 yards on the distance scale. A straight line drawn through these two points and extended across the speed scale intersects the speed scale at 9 knots, answering the problem. If the distance in figure 11-6 is relative, then speed (9 knots) obtained is also relative.

Logarithmic Scale

You actually need only one of the three nonogram scales to solve for time, speed, or distance if you know any two of the three values. But since the upper scale is larger, it will provide greater accuracy.

If you use a single logarithmic scale to solve the basic equation with speed in *knots* and distance in *miles* or thousands of *yards*, you must incorporate either 60 (for miles) or 30 (for yards) into the basic equation for the result to have the proper units. We explain this procedure below.

Figure 11-7 shows how to use the upper scale for finding the speed, in knots, when you know the time in minutes and the distance in miles. In this problem, the time is 10 minutes and the distance is 2 miles. Set one point of a pair of dividers at "10" (the time in minutes) and the second point at "2" (the distance in miles). Without changing the spread of the dividers or the right-left relationship, set the first point at "60". The second point will indicate the speed in knots (12). If you know the speed and time, place one point at 60 and the second point at the speed in knots (12). Without changing the spread of the dividers or the right-left relationship, place the first point at the time in minutes (10). The second point then will indicate the distance in miles (2).

If the distance you use is in thousands of yards, set a divider point at "30" rather than at "60". If the speed is less than 30 knots, the distance in thousands of yards will always be less than the time in minutes. If the speed is in excess of 30 knots, the distance in thousands of yards will always be greater than the time in minutes.

CLOSEST POINT OF APPROACH PROBLEMS

When range, bearing, and composition of a radar contact are relayed to the bridge, the OOD expects amplifying information shortly afterward about the contact's course, speed, and closest point of approach.

The closest point of approach (CPA) is the position of a contact when it reaches its minimum range to own ship. This point is at the intersection of a line from own

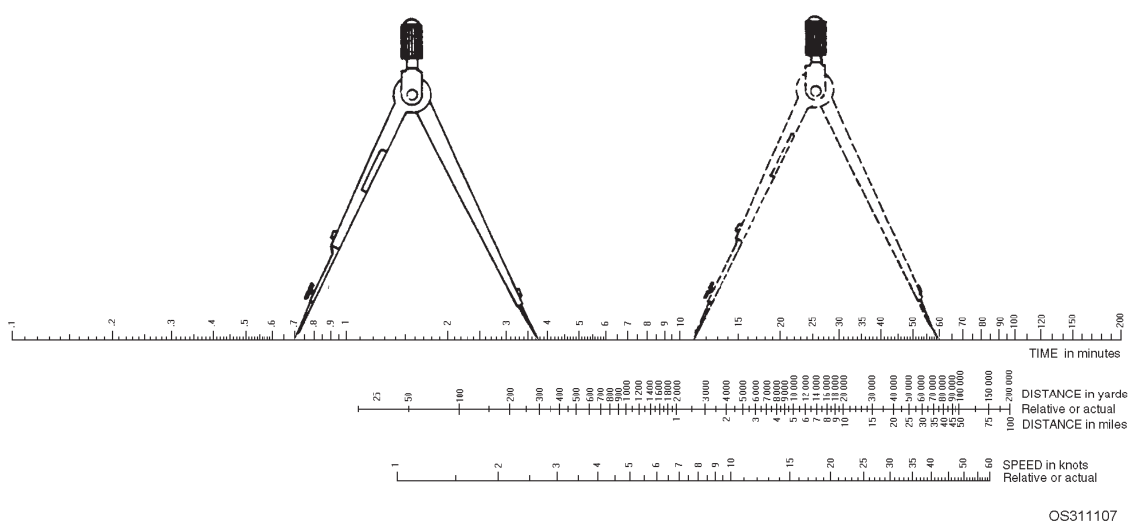

Figure 11-7.—Logarithmic scale.

ship to the contact's line of relative movement, perpendicular to the line of relative movement. It is expressed in *true* bearing and range from own ship and the time the contact should reach that point.

You can find the point and time of a contact's CPA on a maneuvering board or the surface summary plot before you solve a vector diagram for the contact's course and speed.

Normally, four plots are needed to get an accurate CPA and time of CPA solution. Check the solution approximately every 3 minutes to see if the solution still is correct. Any change in course or speed of either own ship or the other ship will result in a change in the CPA.

NOTE

> Unless indicated otherwise, all courses and bearings are true (T). Also, for the problems in this chapter, you may notice slight discrepancies between the plots in the figures and the numerical solutions stated in the text. These discrepancies are within tolerances allowed (±3°, ±3 knots, ±3 minutes, and ± 500 yards) for maneuvering board problems.

Problem #1

Situation: Own ship is on course 300°, speed 15 knots. See figure 11-8. At 0530 the surface-search radar operator reports a surface contact on bearing 236° at 18,000 yards, closing. The radar operator continues to report ranges and bearings. At 0533 the contact has closed to 15,600 yards on bearing 232°. (Note: Although we stated earlier that you need four plots to get an accurate CPA solution, we will use only two points in this problem to simplify the process.)

You must determine the following information:

1. The direction of relative motion (DRM) of the contact with respect to own ship
2. The true bearing of the contact when it reaches minimum range
3. The minimum range at which the contact will pass own ship
4. The speed of relative motion of the contact with respect to own ship
5. The time at which the contact will reach CPA

Solution: As with any maneuvering board problem, your first consideration is the choice of scale. Since the contact's initial range is less than 20,000 yards but greater than 10,000 yards, the 2:1 scale is the most suitable one to fit the board and present the largest picture, enabling you to get the most accurate solution.

Determining Closest Point of Approach

First, construct a track of the contact to establish its M_1M_2, line of relative movement. Extend this line across the maneuvering board. Label the first plot M_1 and the second M_2.

Next, determine the contact's DRM. To obtain the direction of relative movement, align one side of the parallel ruler along the $M_1 M_2$ line, then walk the rulers until the other side is positioned over the center of the maneuvering board. Mark the bearing circle at the point where the ruler on the center point crosses it. In this problem (fig. 11-8), a line drawn through the board's center and parallel to the relative movement line will cross the bearing circle at bearing 081°, so DRM is 081°.

Sometimes when you attempt to draw a contact's line of relative movement, you will find that the plot points (M_1, M_2, M_3, etc.) are not in a straight line. This may have been caused by someone's error in reporting or plotting bearing or range. If the plot is erratic, imagine a line that runs through the average or mean of the plots. Lay one edge of the parallel ruler on this line, then walk the ruler to the center of the board to find the DRM.

From the center of the board, construct a line that is perpendicular to the extended M_1M_2 line. You can make a perpendicular-to-the-relative-movement line by adding 90° to, or subtracting 90° from, the DRM, depending on the general direction from own ship to the contact. In this case, we need to add 90° to the DRM. Thus, the true bearing of the contact when it reaches its minimum range from own ship is 171° (081° + 090° = 171°). (When the answer exceeds 360°, subtract 360 from the total to obtain the CPA bearing.)

The point where the bearing line crosses the extended M_1M_2 line is the range of CPA. Measure this range from the center of the board by applying the same scale (2:1) you used to plot the positions of the contact. In the example, the range is approximately 7700 yards. This means that 7700 yards is the closest point the contact will pass to own ship, provided that neither ship changes course or speed.

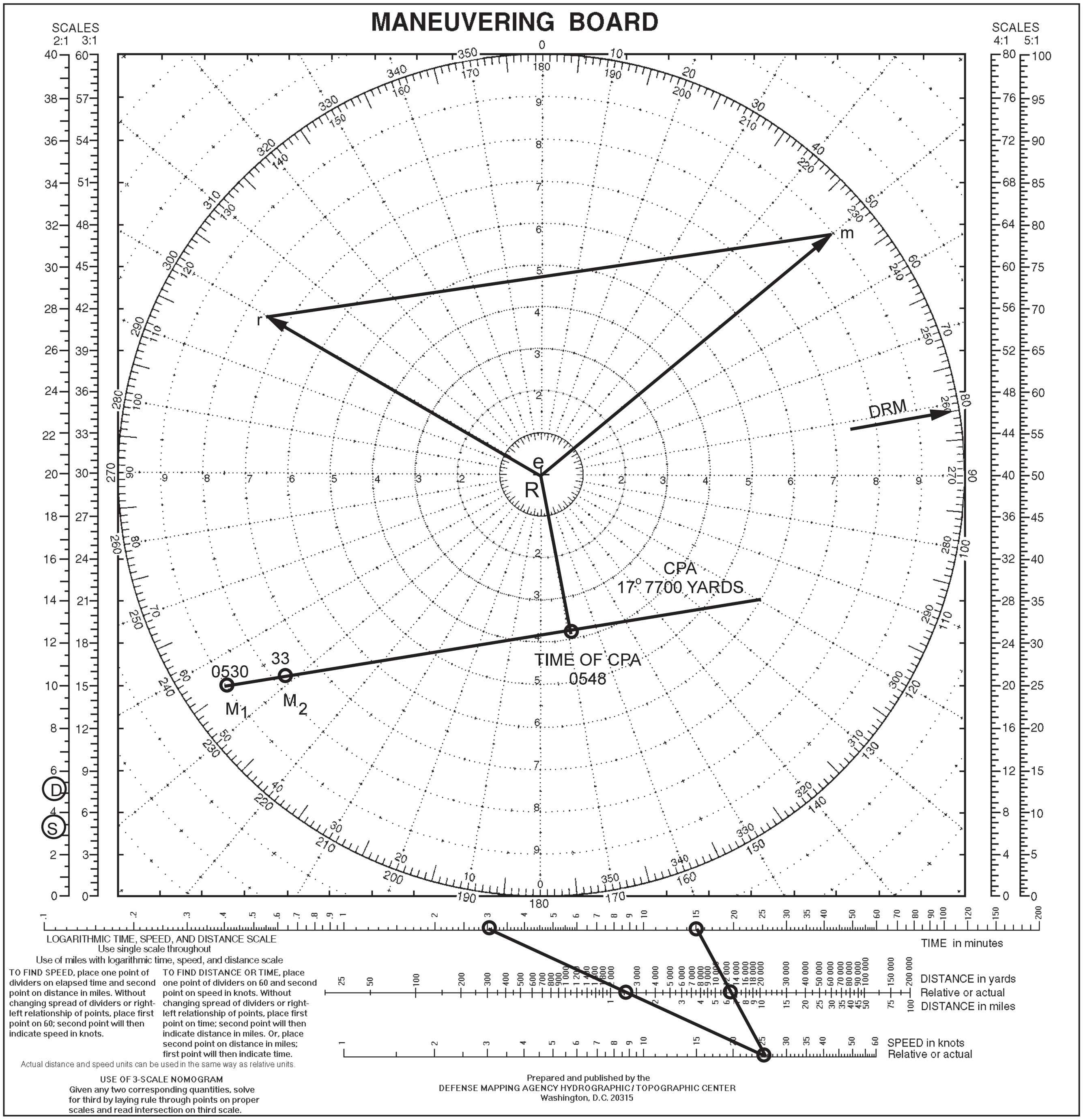

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Figure 11-8.—Course, speed and CPA problem

So far, we know the range and true bearing at which the contact will be closest to own ship. Now we need to know the time of CPA.

Determining Time of CPA

To calculate the time at which the contact will be at CPA, you must first determine the relative distance from point M_2 to the point of CPA and the contact's relative speed.

To obtain the relative speed, first measure the distance the contact moved during the 3-minute interval between 0530 and 0533. The relative distance from M_1 to M_2 is 2700 yards. Since you know a distance and its associated time, you can use the nomogram to determine the related speed. Locate 3 minutes on the time scale, then 2700 yards on the distance scale (see figure 11-8). Next, draw a straight line between the two points and extend the line through the speed scale.

The point where the line cuts across the speed scale indicates the relative speed of the contact, in this problem, 27 knots.

Determine the relative distance to CPA by measuring the distance from M_2 to CPA (13,750 yards).

You can now determine the time of CPA by applying the relative speed (27 knots) and the relative distance (13,750 yards) to the nomogram. By laying a straightedge through these two points, you will obtain a time of 15 minutes. This means that the contact will be at CPA 15 minutes from the time of M_2, or at time 0548.

CPA problems are common types that you will solve many times while standing watch in CIC. Many times, you will work them on the surface summary plot. Inasmuch as the surface plot does not have a nomogram on it, you will have to use a nautical slide rule. See figure 11-9. You will use the nautical slide rule in the same manner as the nomogram, but in many instances you will find the slide rule easier to use. If you have any doubt about using it, be sure to ask a senior Operations Specialist.

3-Minute Rule

The 3-minute thumb rule is another method of solving for relative speed. You can use it instead of the nomogram or a nautical slide rule to determine relative speed, thus saving considerable time. The 3-minute rule can be summarized in three short steps, as follows:

1. Compute the distance, in yards, traveled in 3 minutes of time.
2. Point off two places from the right.
3. The result is speed in knots.

Thus, a ship that travels 2700 yards in 3 minutes has a speed of 27 knots.

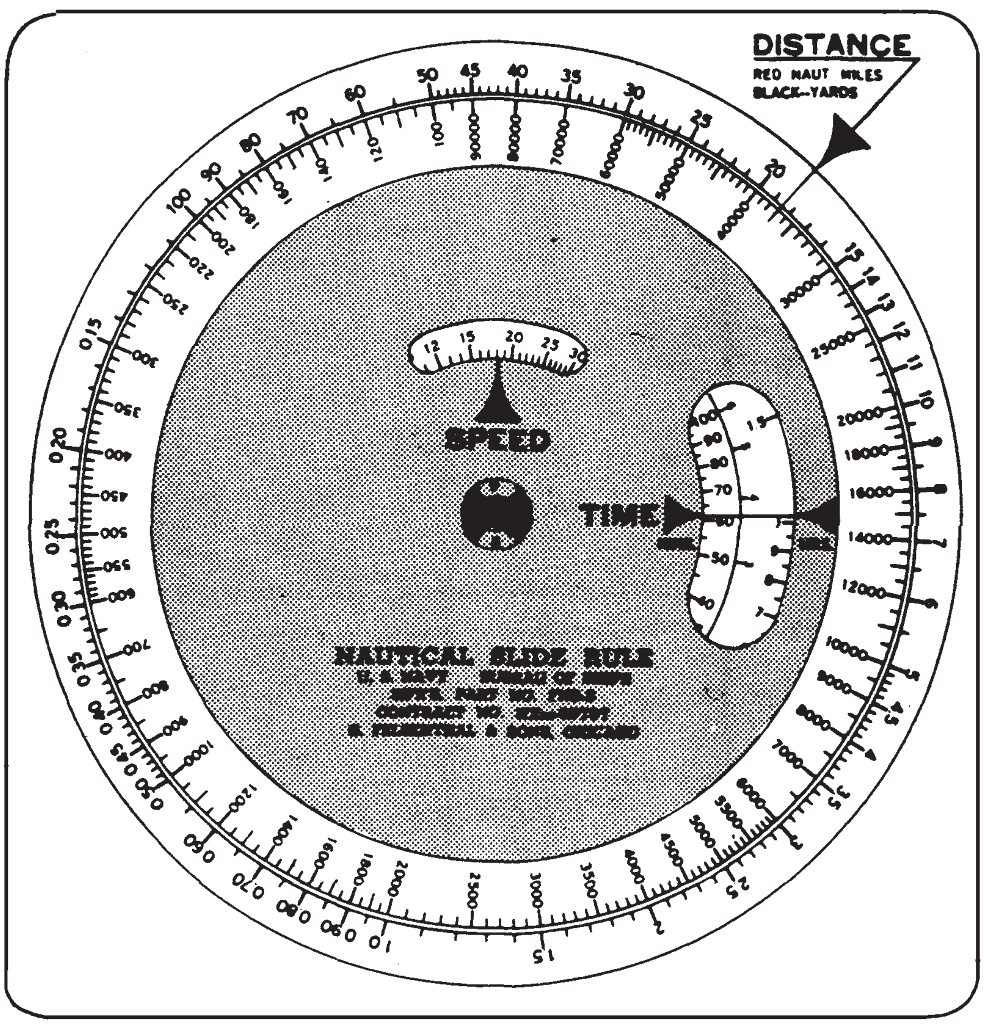

Figure 11-9.—Nautical slide rule.

Q2. Regardless of the method used to do a maneuvering board problem, where is the reference ship plotted?

Q3. What scale on the maneuvering board is used to solve for time, speed, or distance?

COURSE AND SPEED PROBLEMS

To illustrate the procedures used to obtain the course and speed of a contact, let's use the situation in the previous problem.

Own ship's course and speed are 300°, 15 knots. In figure 11-8 these are plotted as vector *er*. In this case, the outer ring represents 20 knots to make the er vector as long as possible to give the most accurate results (If the outer ring were set at 10 knots, vector *er* wouldn't fit on the board. If the outer ring were set at 30 knots, vector *er* would be shorter than it is in the figure).Since vector *er*, originates in the center of the maneuvering board, it is a true vector.

You can use much of the information you obtained in the CPA problem to also determine the contact's true course and speed. To do this, you must first draw vector *rm*, which represents the contact's DRM and relative speed.

To draw vector *rm*, first draw, through the end of vector *er*, a line of some length representing DRM. We mentioned earlier that line M_1M_2 (which represents DRM) and the vector *rm* are always parallel, and that the direction M_1 to M_2 is always the same as the direction *r* to *m*. To draw the *rm* line, place one side of your parallel rulers on line M_1M_2. Now, use the rulers to draw a line parallel to M_1M_2 through the end of vector *er.* This line represents the direction of vector *rm*. To establish the length of vector *rm*, set your dividers to 27 knots on the 2:1 speed scale. You must use the 2:1 scale because we earlier set the outer ring of the maneuvering board equal to 20 knots. Now, place one of the dividers' points at point r and the other point on the line in the direction of DRM. Label the second point m. You have drawn vector *rm*.

To determine the true course and speed of the contact, simply complete the vector diagram by drawing a line from the center of the maneuvering board to the end of the *rm* vector. This line is the *em* vector. Its direction indicates the target's true course; its length indicates the target's true speed. In this example, the contact is on course 050°, speed 18 knots.

IMPORTANCE OF LABELING

To avoid confusion, be sure to label each line or vector of the relative plot and vector diagram correctly. In addition, also mark the scales you are using. Notice in figure 11-8 that the 2:1 scale is marked with D and S. This means that the 2:1 scale is being used for both distance (D) and speed (S). These scale markings are particularly important when one scale is being used for distance and a different scale is being used for speed.

PRACTICE PROBLEMS

By now, you should have a basic understanding of how to use the maneuvering board. To help you develop skills in working various types of problems, we will now present and solve several problems associated with typical situations.

Course, Speed, and CPA Problems

Problem #1

1. Own ship's course is 090°, speed 10 knots.
2. At time 1100, Skunk A is bearing 060°, range 10,000 yards.
3. At 1101, Skunk A bears 059.5°, range 9400 yards.
4. At 1102, Skunk A bears 059°, range 8600 yards.
5. At time 1103, Skunk A bears 058°, range 8,000 yards.

Find the following:

1. CPA
2. Time of CPA
3. Course and speed of Skunk A

This problem is laid out for you in figure 11-10. Study it carefully and make sure you understand every vector and solution before proceeding any further. The answers are as follows:

1. CPA: 338°, 1300 yards
2. Time of CPA: 1115
3. Course and speed of Skunk A: 228°, 11.5 knots

Problem #2

1. Own ship's course 270°, speed 27 knots.
2. At time 1200, Skunk B is reported at 284°, range 18,000 yards.

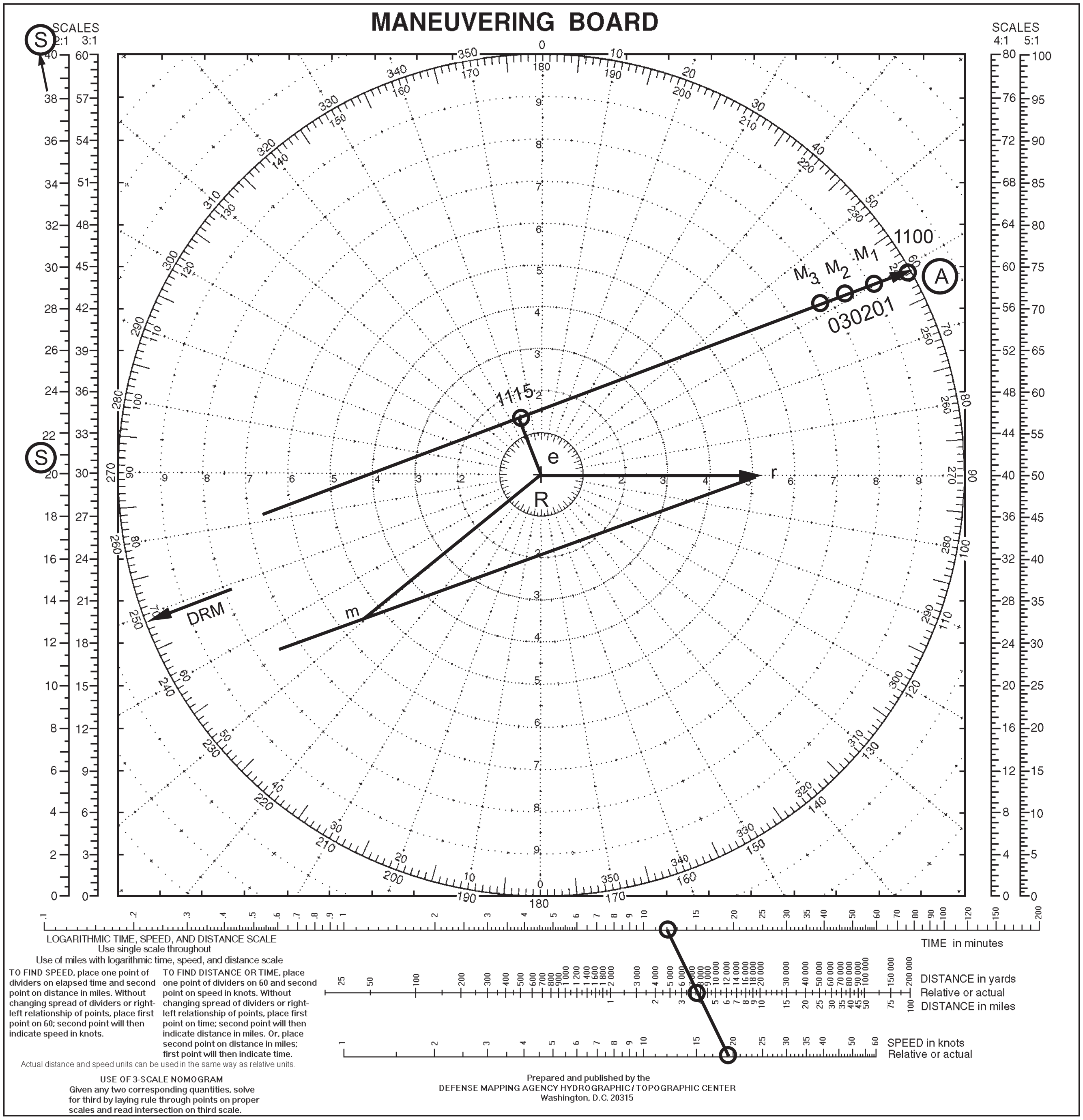

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Figure 11-10.—Course, speed and CPA problem #1.

3. At time 1202, Skunk B bears 286.5°, range 15,200 yards.
4. At time 1204, Skunk B bears 288.5°, range 12,500 yards.
5. At time 1205, Skunk B bears 291°, range 11,100 yards.

Find the following:

1. CPA
2. Time of CPA
3. Course and speed of Skunk B

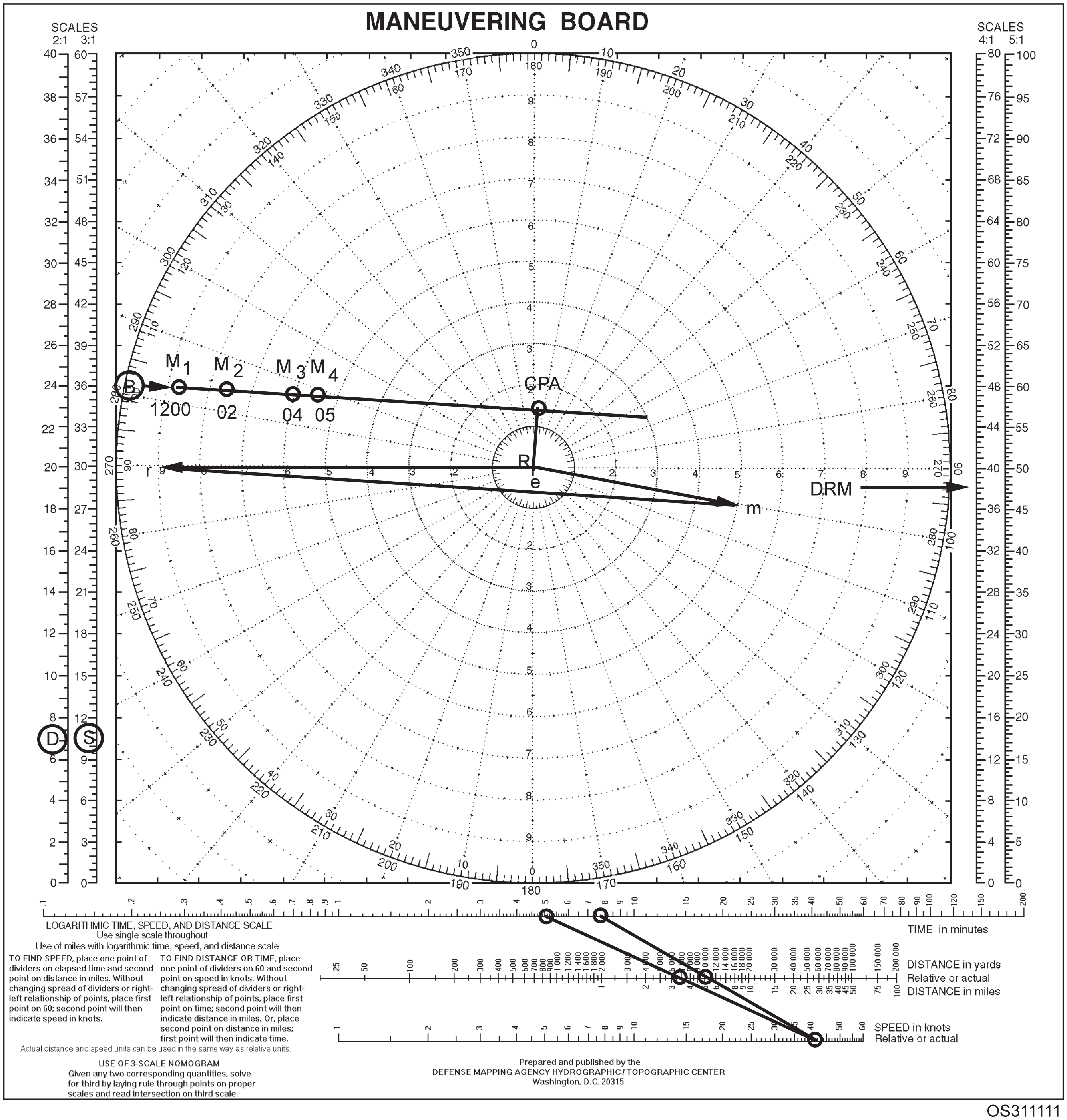

Figure 11-11.—Course, speed and CPA problem #2.

This problem is shown in figure 11-11. Did you get the correct solutions? The answers are as follows:

1. CPA: 003°, 3450 yards
2. Time of CPA: 1212
3. Course and speed of Skunk B: 097°, 16 knots

Change-of-Station Problems

To determine the required course or speed of the maneuvering ship to go from one station to another, use basically the procedures as you used for the course and speed problems.

Problem #1

The formation is on course 020°, speed 12 knots. You are on board the flagship. Cruiser A is 18,000 yards ahead of you and is ordered to take station on the port beam of the flagship, distance 14,000 yards.

Find the following:

1. The direction of relative movement of cruiser A with respect to your ship
2. Cruiser A's course at 18 knots
3. Cruiser A's course at 12 knots
4. Cruiser A's speed if she steers 295°
5. Cruiser A's speed if she steers 350°

Solution: (Recommend the use of a scale of 2:1 for distance and speed.)

1. Draw vector *er* to represent the true course and speed of your ship.
2. Locate M_1 and M_2 and draw the line of relative motion. To locate these points, determine the true bearing of the maneuvering ship from the reference ship at the beginning and end of the maneuver. Thus, if cruiser A is ahead of you at the start of the maneuver and you are on course 020°, her true bearing from you is 020°; the distance is 18,000 yards, as given. M_2 is on your port beam, or at a relative bearing of 270° (290°T), and the distance is 14,000 yards. Place an arrowhead on the relative movement line to indicate that the direction is from M_1 to M_2. You can determine the direction of this line by transferring it parallel to itself to the center of the diagram.
3. Draw vector *rm*, parallel to $M_1 M_2$. Begin this line at r, and continue it until it intersects the 18-knot speed circle (circle 9 at 2:1 scale). Label this point m_1.
4. Complete the speed triangle by drawing vector em_1 from the center of the diagram to m_1. The direction of this line represents the course required to produce the desired DRM at a speed of 18 knots.
5. Draw vector em_2 from the center of the diagram to the intersection of the *rm* vector with the 12-knot circle.
6. Draw vector em_3 in the direction 295° from the center to its intersection with the *rm* vector. The length of this line represents the true speed at 295°.
7. Draw vector em_4 vector in the direction 350°, determining the speed as in step 6.

Any of these combinations of course and speed of cruiser A will produce the desired relative movement.

Check your plot against figure 11-12. The answers are as follows:

1. DRM: 238°
2. Course: 262°
3. Course: 276°
4. Speed: 8.8 knots
5. Speed: 8 knots

Which of the four courses and speeds would take the greatest amount of time? Why?

Answer: Course 350°, speed 8 knots would take the greatest time, because relative speed is slowest on that course (rm_4).

If cruiser A desires to get to its new station as fast as possible, it should take the course and speed that has the highest relative speed: course 262°, speed 18 knots.

If cruiser A takes course 350° at 8 knots to go to its new station, its relative speed will be 6.4 knots. The maneuver will require 1 hour and 47 minutes to complete. However, if the cruiser takes course 262° at 18 knots, its relative speed will be 25.9 knots. It will arrive at its new station in 26 minutes. Thus, cruiser A's best course to station is 262° at 18 knots.

Problem #2

A formation is on course 090° at 15 knots. Destroyer B is located broad on your starboard bow at 20,000 yards. Destroyer B is ordered to take station 4,000 yards on your port beam, using a speed of 12 knots.

Find the following:

1. Destroyer B's best course to station at 12 knots
2. Destroyer B's time to station
3. Destroyer B's CPA to own ship

Solution:

1. Draw vector *er*: 090°, 15 knots.
2. Locate M_1 and M_2 (M_1 is at 135°, 20,000 yards; M_2 is at 000°, 4,000 yards), and draw the DRM line.

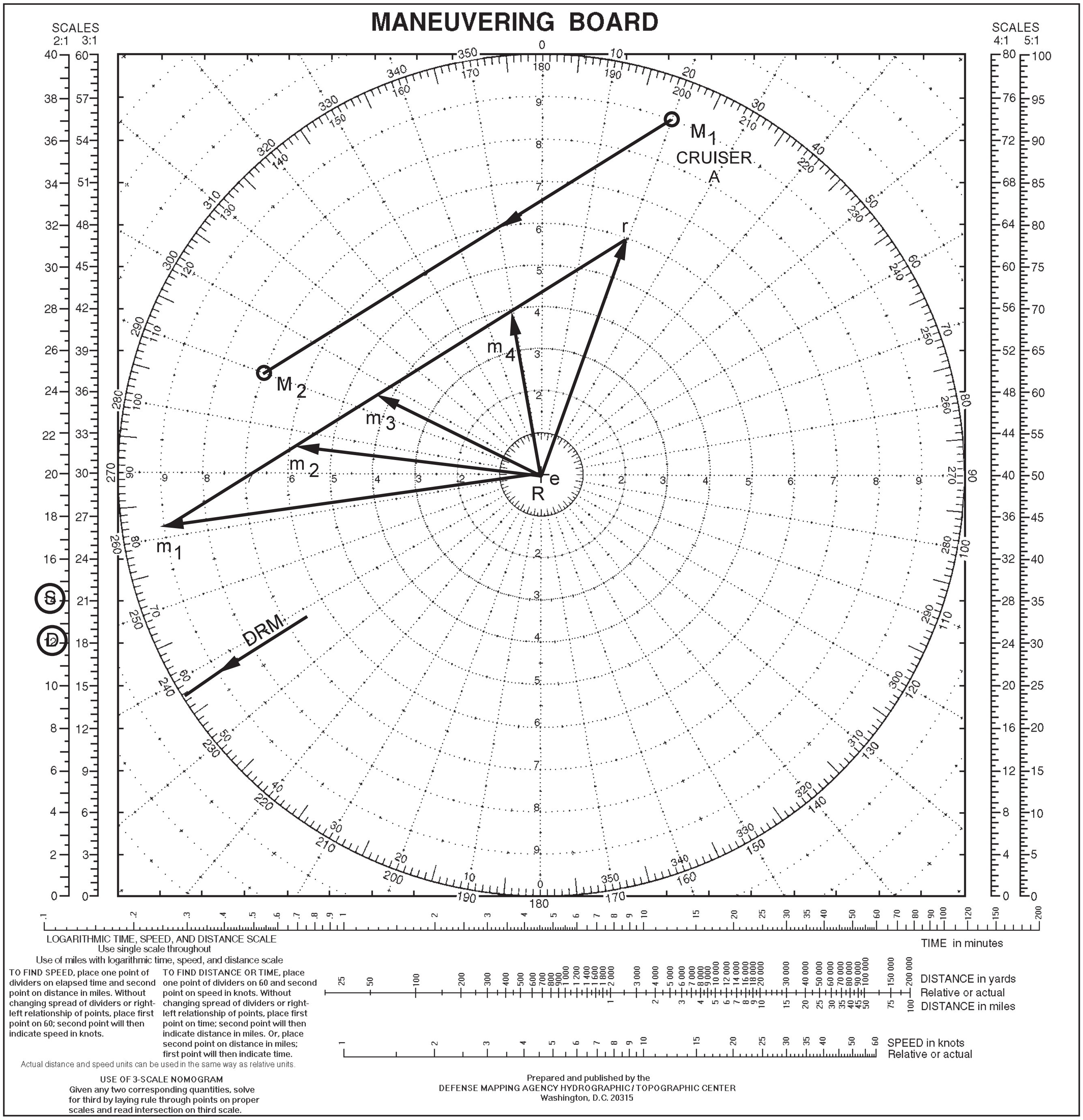

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Figure 11-12.—Change-of-station problem #1.

3. Parallel the DRM line to the end of the *er* vector. This establishes the direction of the *rm* vector.
4. Complete the vector triangle by drawing vector *em* from the center to the point where the *rm* line crosses the 12-knot circle with the highest relative speed (the *rm* line crosses the circle at two points).
5. Determine relative speed by measuring the length of the *rm* vector.
6. Determine the relative distance destroyer B has to go to station by measuring the distance from M_1 to M_2.
7. Apply the relative speed and the relative distance to the nomogram to determine the time required to complete the maneuver.
8. Determine DRM and add 90° to obtain the CPA bearing (322° + 90° - 360° = 052°).

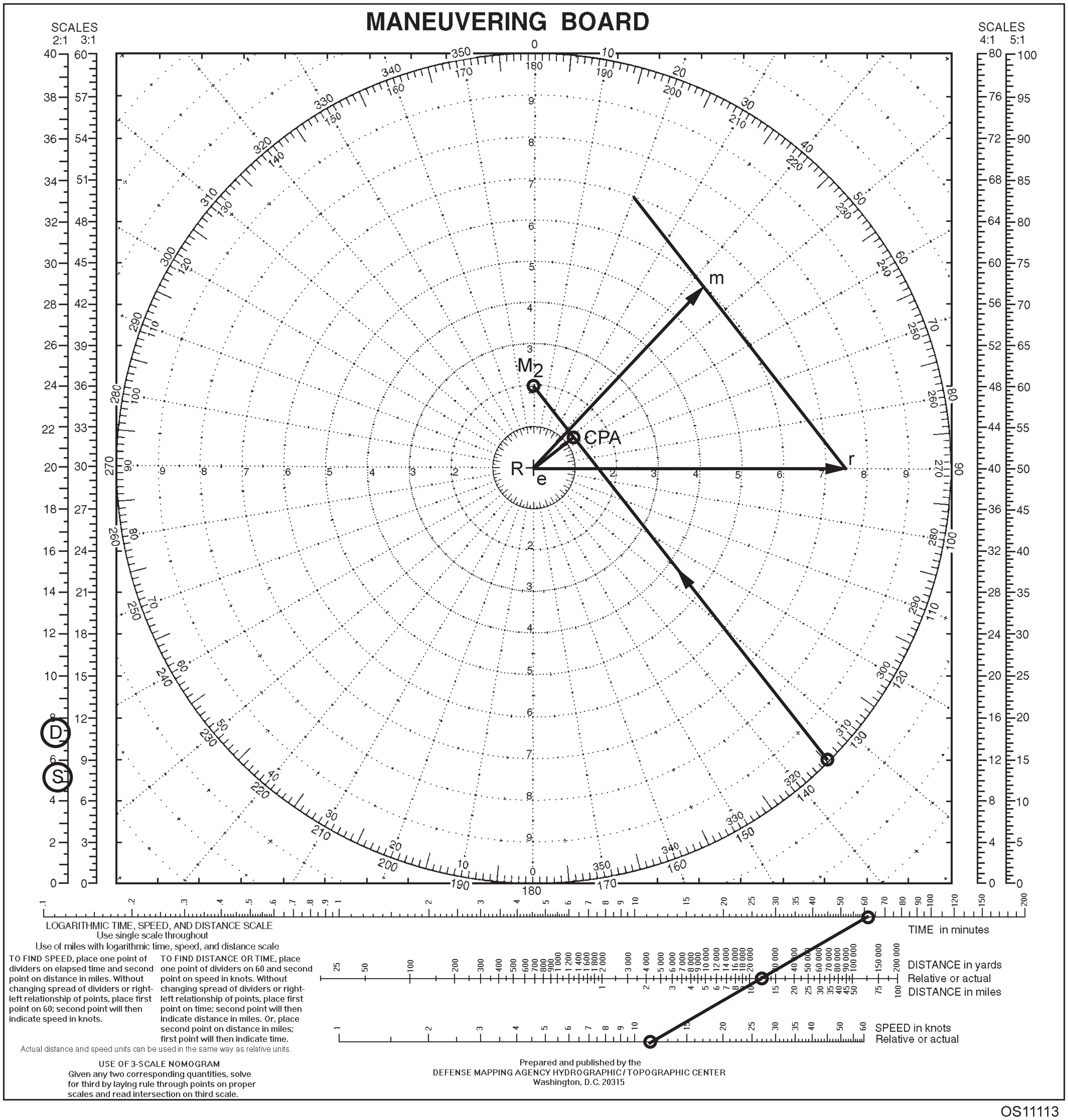

Figure 11-13.—Change-of-station problem #2.

9. Draw a line from the center out along the CPA bearing to the point where it intersects the M_1M_2 vector.
10. Measure the distance from the center to the CPA.

Check your plot against figure 11-13. The answers are as follows:

1. Course: 043°
2. Time to station: 61 minutes
3. CPA: 052°, 2500 yards

Problem #3

Own ship is steaming independently on course 180°, speed 15 knots. You are in communications with destroyer C located at 140°, 36,000 yards at time 2000. He states that he will be passing through your area on course 270° at 20 knots.

Find the following:

1. Destroyer C's CPA
2. Time to CPA.

Solution:

1. Draw the *er* vector: 180°, 15 knots.
2. Draw the *em* vector: 270°, 20 knots.
3. Complete the vector diagram by drawing the *rm* vector.
4. Plot the M_1 position: 140°, 36,000 yards.
5. Determine DRM by paralleling the *rm* vector to the center. Direction is always from *r* to *m*; therefore, DRM is 307°.
6. Parallel to the M_1 position and draw a line from M_1 across the maneuvering board.
7. Subtract 90° from the DRM to determine the CPA bearing (307° - 90° = 217°).
8. Determine CPA range by drawing a line from the center out along the CPA bearing to the point where it intersects the extended DRM line.
9. Determine relative speed by measuring the length of the *rm* vector.
10. Determine the relative distance by measuring the distance from M_1 to CPA.
11. Determine time to CPA by applying relative speed and relative distance to the nomogram.

Check your plot against figure 11-14. The answers are as follows:

1. CPA: 217°; 8,100 yards
2. Time to CPA: 42.5 minutes

Avoiding Course Problem

To solve for avoiding a collision, use the same basic change-of-station procedures. The primary difference is in how you document the situation.

Problem:

Your ship is steaming independently on course 320°, speed 15 knots. You track a contact for a reasonable amount of time and determine that its course and speed are 197°, 20 knots and that it is on a collision course with your ship. The contact bears 353°, range 16,000 yards at time 0250. When the contact reaches 10,000 yards, your ship is to take action to avoid the contact by 3,000 yards, while not crossing its bow. You will also be required to maintain your present speed throughout the maneuver.

Find the following:

1. Course to steer to avoid the contact
2. Time to turn

Solution:

1. Draw the er_1 vector: 320°, 15 knots.
2. Draw the *em* vector: 197°, 20 knots.
3. Complete the vector diagram. Draw r_1m.
4. Plot the M_1 position: 353°, range 16,000 yards.
5. Plot the M_2 position: 353°, range 10,000 yards.
6. Draw a line from M_2 tangent to the 3,000-yard circle. To avoid crossing the contact's bow, own ship will have to turn right. Therefore, the line will be drawn to the west of own ship. Parallel this line to the *em* vector and draw the r_2m 15-knot circle. Complete the vector diagram by drawing er_2.
7. To determine the time to turn, measure the M_1 M_2 distance and relative speed of r_1m. Apply these components to the nomogram and add the results to the time designated for the M_1 position.

Check your solution against figure 11-15. The answers are as follows:

1. 003°
2. 0256

Wind Problems

Relative wind is the direction and speed from which the wind *appears* to be blowing. Relative wind seldom coincides with true wind, because the direction and speed of the relative wind are affected by own ship's movement. For example, if your ship is heading north at 10 knots and the true wind is blowing from the south at 10 knots, there appears to be no wind at all. In another situation, your ship may be heading north with the wind appearing to blow in on the port bow, but the true wind is actually coming from the port quarter. In both of these cases, the ship's movement is affecting the relative wind.

You can figure wind problems on a maneuvering board by using basically the same procedures as for course and speed problems. There are, however, a few new terms:

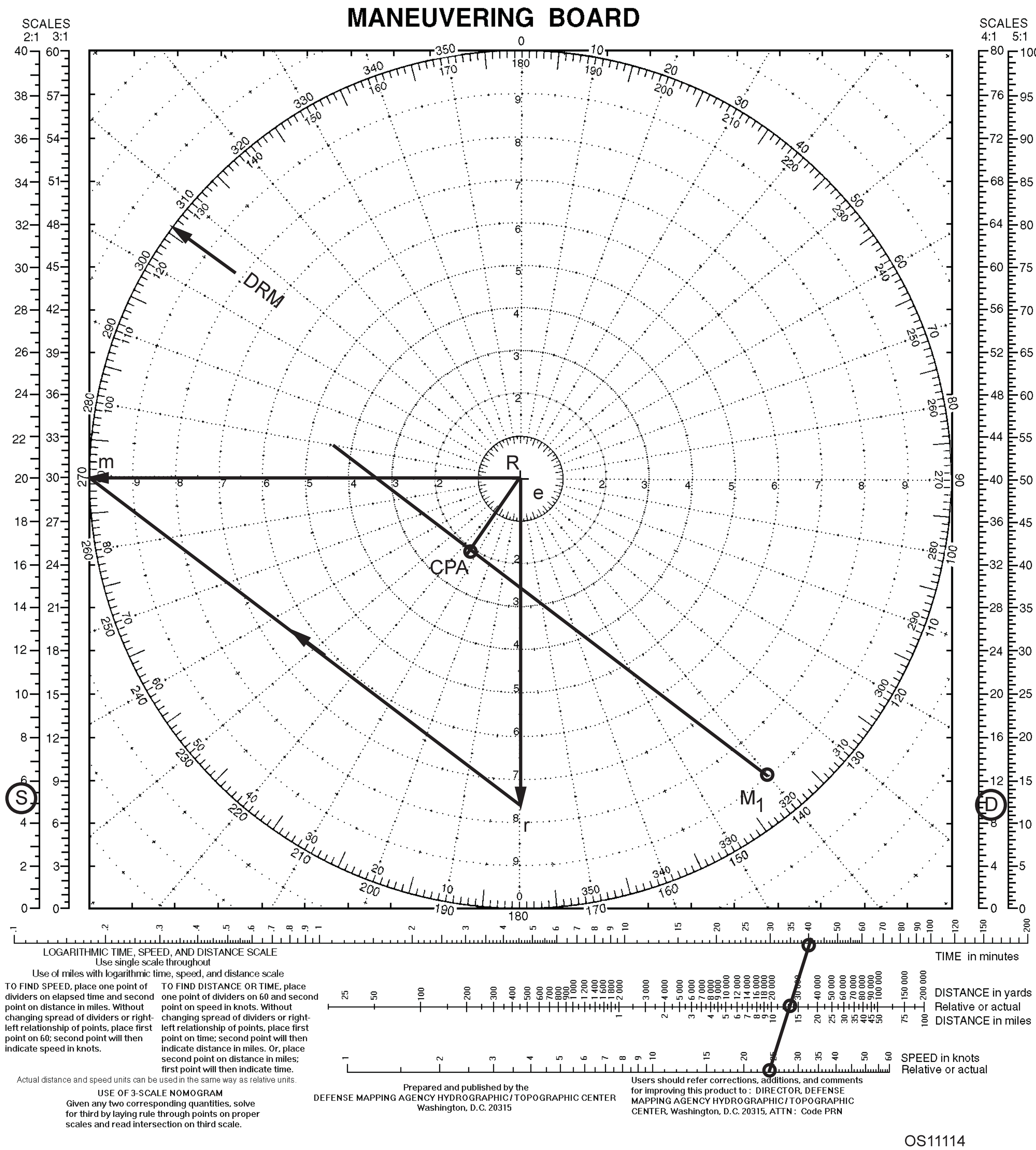

Figure 11-14.—Change-of-station problem # 3.

course and speed problems. There are, however, a few new terms:

1. True wind (TW) is the velocity and direction from which the true wind is blowing.

2. Relative wind (RW) is the velocity and relative direction from which the wind is blowing in relation to ship's head (SH).

3. Apparent wind (AW) is the velocity and true direction from which the relative wind is blowing. For example, if your ship is heading 090° and a 15-knot relative wind is blowing in on your starboard bow (045°), the apparent wind is from 135°T at 15 knots. The formula for apparent wind is AW = RW +SH.

4. An anemometer is an instrument for measuring the velocity of the wind. Some shipboard anemometers indicate relative wind, while others indicate apparent wind.

When determining true wind, you must be careful to note whether relative or apparent wind is given.

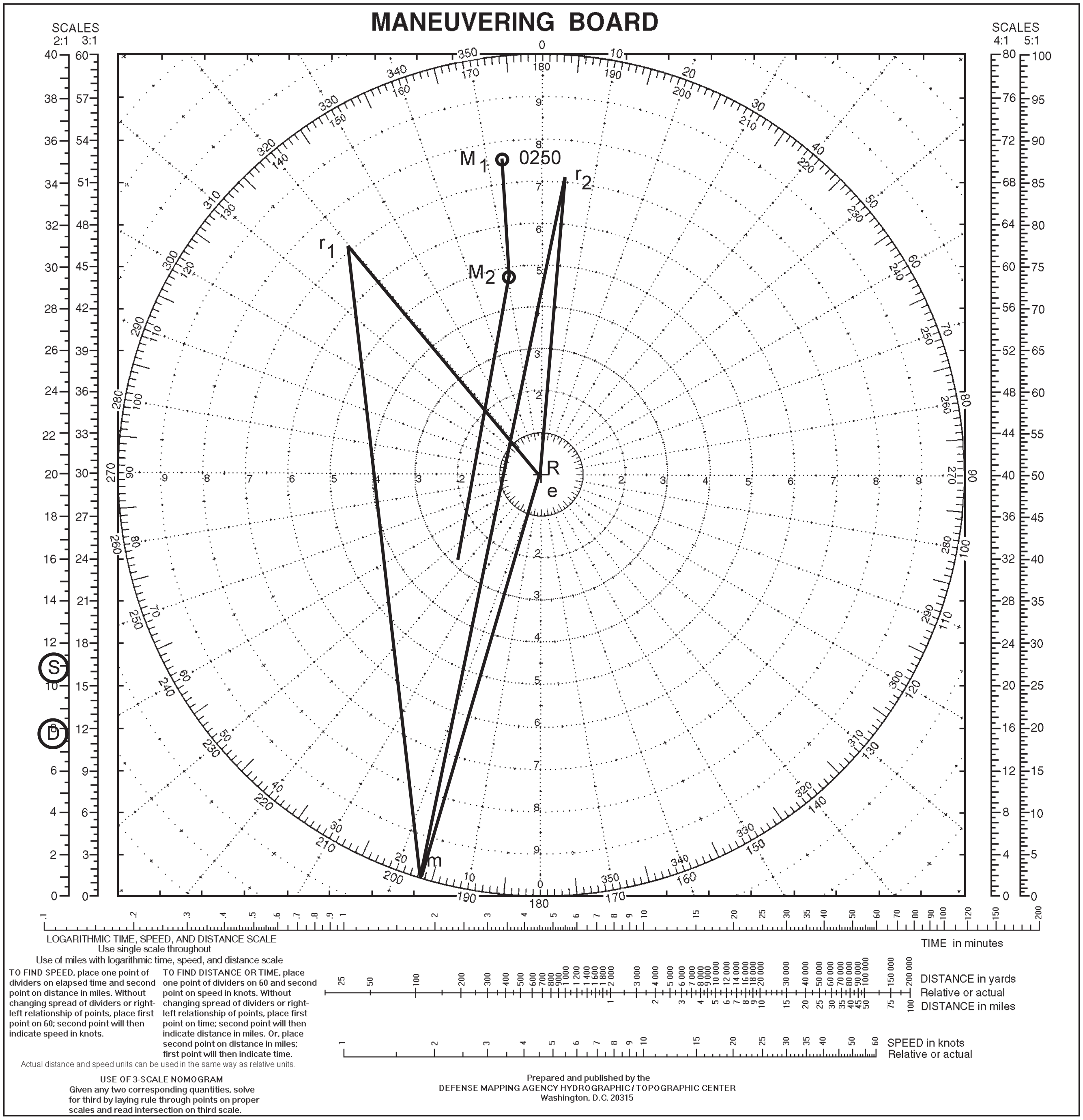

Figure 11-15.—Avoiding course problem.

Wind direction is always the direction from, NOT to which the wind is blowing.

In the vector diagram for a wind problem, the vectors are labeled as follows:

1. *er*—own ship's course and speed
2. *et*—true wind
3. *ra*—relative wind

Remember, wind is always expressed in terms of the direction it is coming from, and the et and ea vectors are the direction and speed of the true and relative wind.

NOTE

You will not draw the ea vector on the maneuvering board, but you must visualize it.

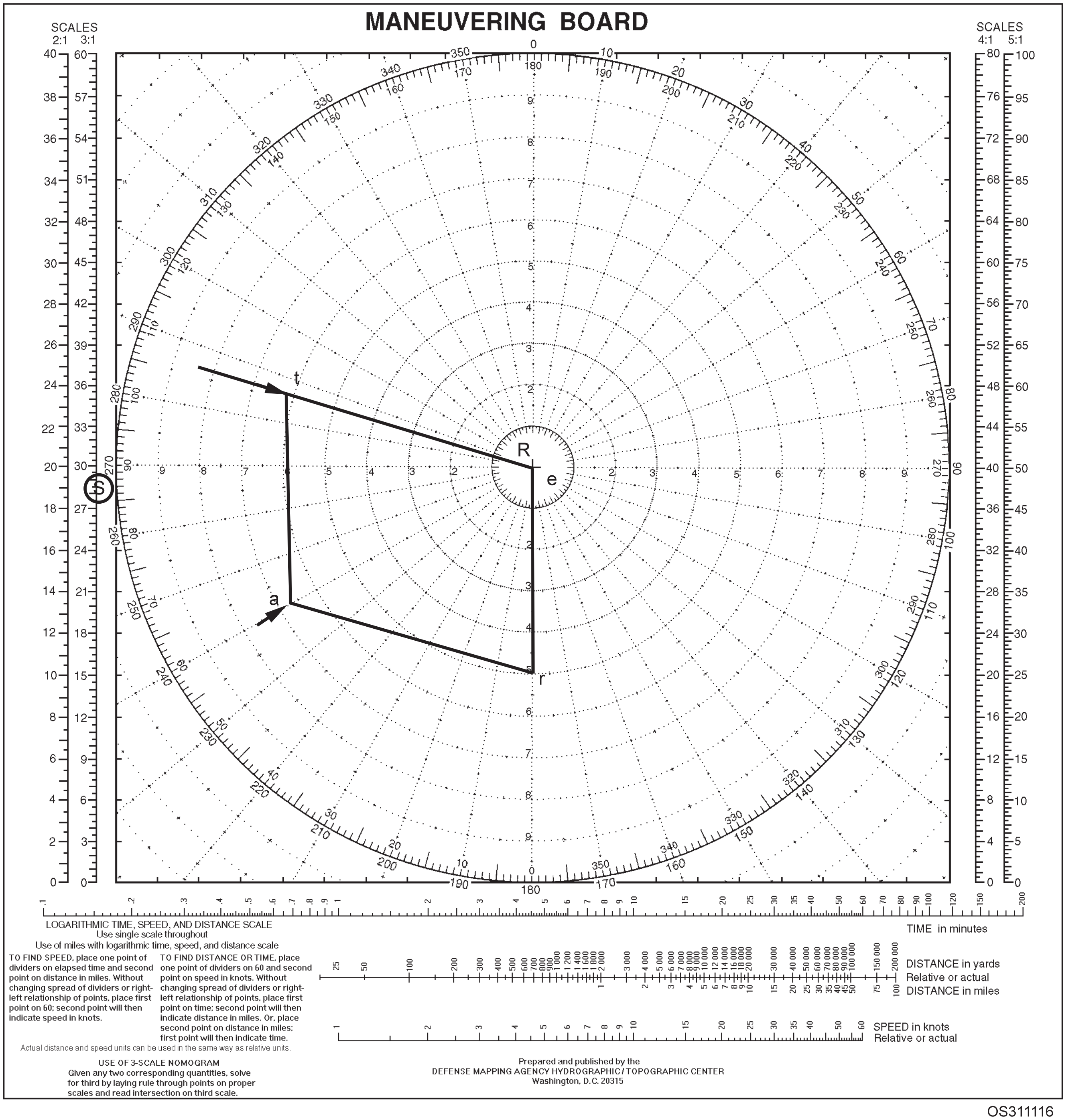

Figure 11-16.—Vector diagram for a wind problem.

Figure 11-16 shows the vector diagram for a typical wind problem. In this case, own ship's course is 180°, speed 15 knots. Draw this as vector *er*. The relative wind is from 060°R at 20 knots. Plot this point and label it as *a*. You can also express relative wind as apparent wind. In this case the apparent wind is 240°T, 20 knots. Plot the relative, apparent, and true wind with the arrows pointing toward the center of the maneuvering board.

Lay the parallel ruler on points *r* and *a* (*ra* vector) and draw a line between the two points. Now draw a line slightly longer than and parallel to the *ra* vector through the center of the maneuvering board. This will be the direction the true wind is coming from (*et*). Now, lay the parallel ruler on the *er* vector (ship's course and speed). Parallel over to the relative wind (*a*) and draw a line until it crosses the *et* vector line that you drew from the center of the maneuvering board. The point where the two lines cross will represent the TRUE wind (direction and speed). When you have worked the problem correctly, you will have drawn a parallelogram with all the points connected (*e* to *r*, *r* to *a*, *e* to *t*, and *a* to *t*).

NOTE

The relative wind will always fall between the ship's head and the true wind.

Problem #1

Own ship is on course 030° at 12 knots. The relative wind is from 310°R at 19 knots.

Find the following:

1. Apparent wind direction
2. True wind velocity and direction

Solution:

1. Relative wind from 310°R at 19 knots converts to an apparent wind from 340°T at 19 knots.
2. Draw vector *er*.
3. Plot point *a*.
4. Parallel the *ra* vector to the center of the maneuvering board and draw a line slightly longer than the *ra* vector.
5. Complete the *et* vector by paralleling the *er* vector to *a* and drawing a line until it crosses the *et* line.

Check your solution against figure 11-17. The answers are as follows:

1. The apparent wind is from 340T.
2. The true wind is from 301 at 14.6 knots.

Problem #2

Own ship's course 250°, speed 20 knots. The apparent wind is from 230°T at 27 knots.

Find the following:

1. Relative wind direction
2. True wind velocity and direction

Solution:

1. The apparent wind from 230°T at 27 knots converts to a relative wind of 340°R at 27 knots.
2. Parallel the *ra* vector to the center of the maneuvering board and draw a line in the direction of *a*.
3. Complete the *et* vector by paralleling the *er* vector to *a* and drawing a line until it crosses the *et* line.

Check your plot against figure 11-18. The answers are as follows:

1. The relative wind is from 340°R.
2. The true wind is from 190° at 11 knots.

Desired Wind Problems

Practically every ship in the fleet conducts flight operations. Flight operations always involve a desired relative wind. Carriers must adjust their course to get the relative wind required to launch or recover aircraft. Even the smallest ships have to make course adjustments to get the relative wind needed for helicopter operations (transfer of mail, personnel, cargo, etc.). In these types of situations, Operations Specialists must solve desired wind problems to determine, from a known true wind, the course and speed the ship must use to obtain the required relative wind.

You must become proficient in computing desired wind problems, since these solutions are almost always provided by CIC. Although there are several methods that you can use to work desired wind problems, the dot method, described in the following paragraphs, is generally considered to be the best.

Problem #1

Assume that true wind is from 180° at 15 knots, and your ship needs a relative wind 30° to port at 20 knots. Follow the steps below on figure 11-19.

1. Draw the true wind course and speed vector from the center of the board toward 000° at 15 knots. (Use the 3:1 scale.) Imagine a ship pointing down the true-wind course line.
2. Plot dot number 1 on the 20-knot circle 30° from the true wind course line, on the port side of the imaginary ship. Before going any farther, be sure you understand this point. As you are looking out from the center, dot 1 is plotted 30° on the port side of the imaginary ship, on the 20-knot circle.
3. Determine the position of dot number 2 by measuring the true wind speed (15 knots in this problem) and swinging an arc from the dot-1 position across the true-wind course line, as shown in figure 11-19. Label the point or points where this arc crosses the true-wind course line

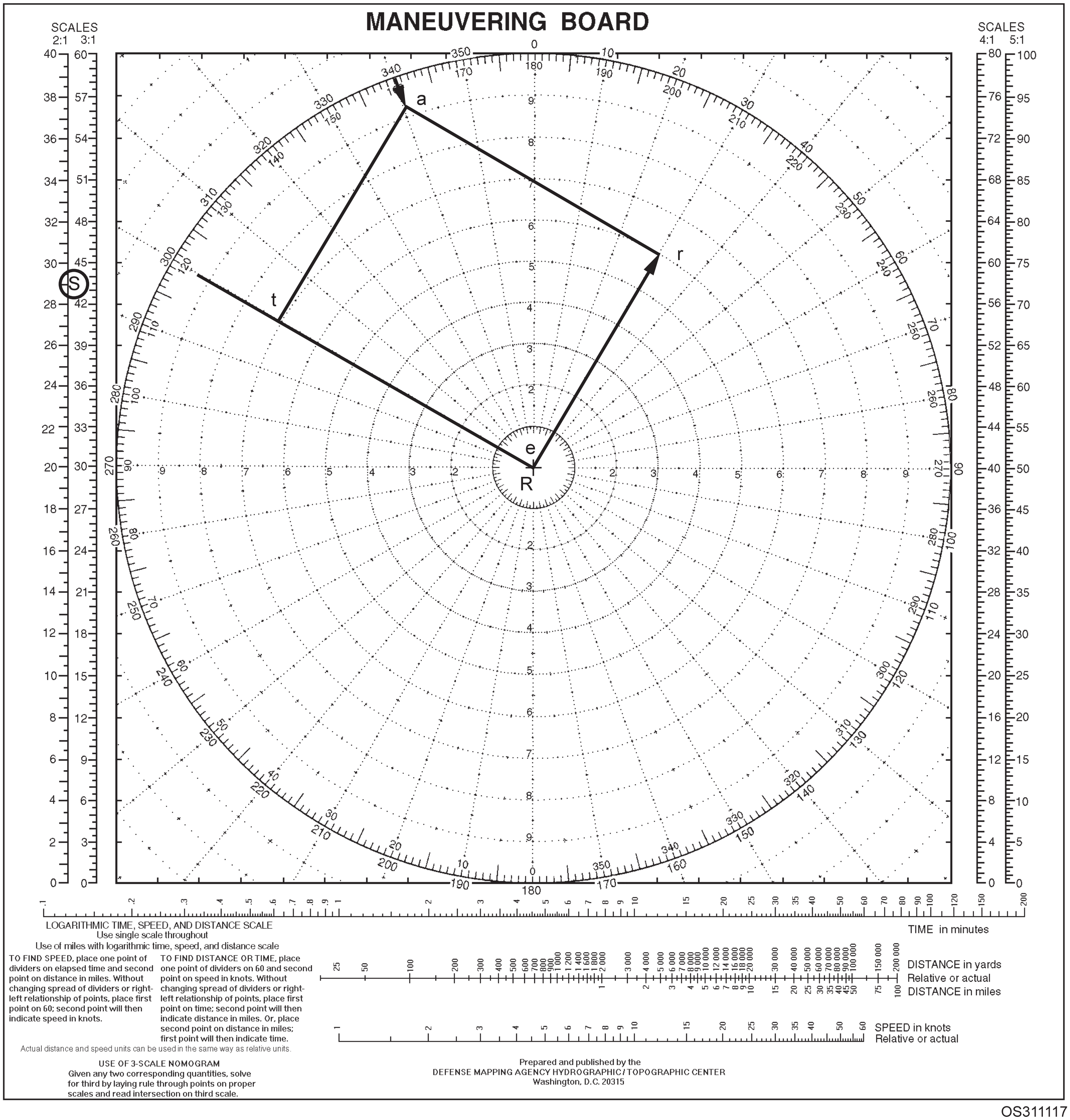

Figure 11-17.—Wind problem # 1.

dot number 2. In most desired wind problems there will be two dot-2 positions, giving you a choice of two different course and speed combinations to obtain the desired wind.

4. Determine the required ship's courses by paralleling the dot 1-dot 2 lines to the center of the maneuvering board. In figure 11-19 the two possible courses are 318° and 222°.

5. Determine the required speed for each course by measuring from the center of the maneuvering board to the associated dot-2 position. If your ship takes course 318°, its speed must be 28.4 knots to obtain a relative wind 30° to port at 20 knots. If it takes course 222°, its speed must be 6.2 knots.

6. Complete the two *er* vectors by laying each speed onto its course line. The ship's

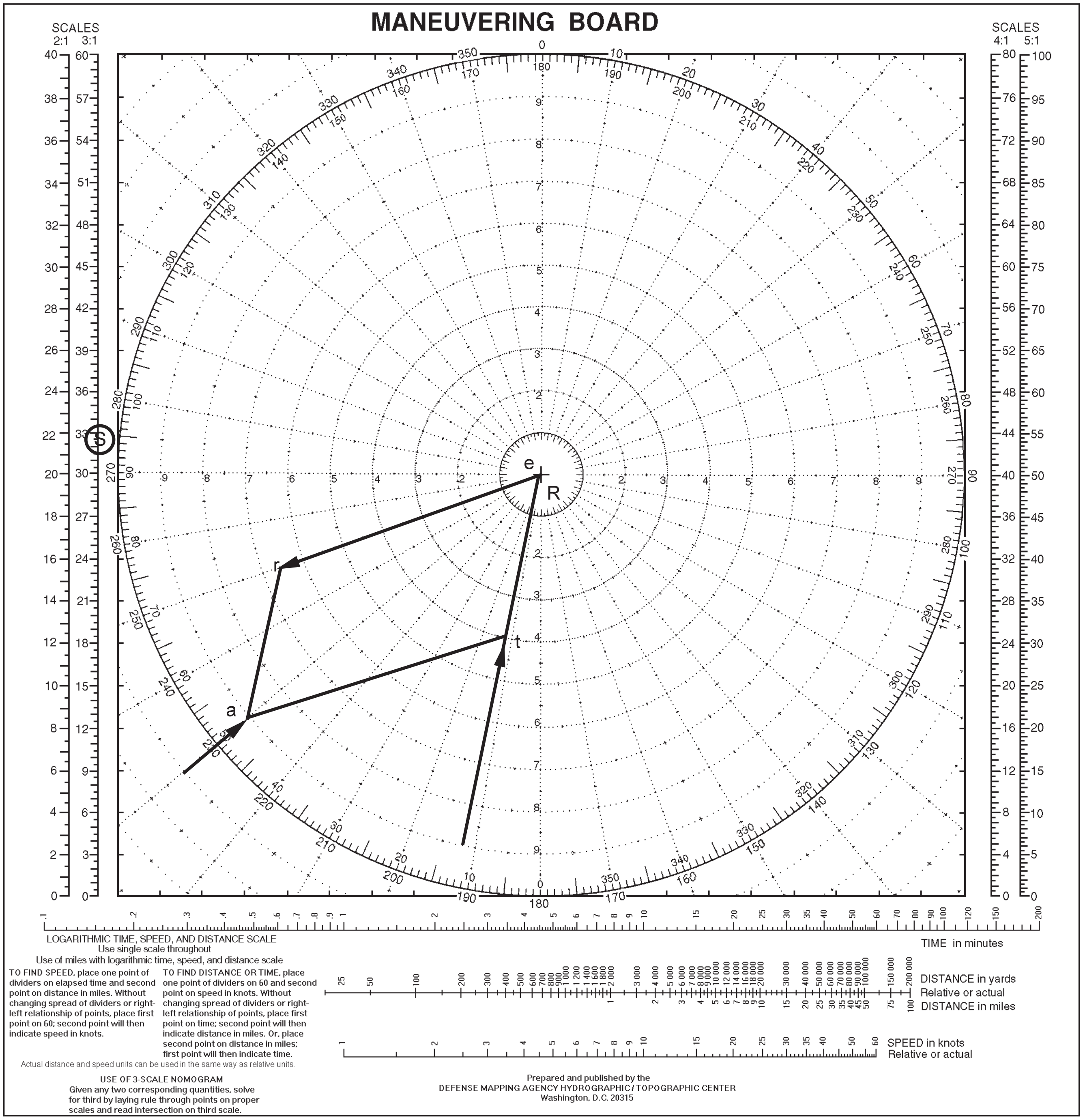

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Figure 11-18.—Wind problem #2.

characteristics and the tactical situation will usually dictate which of the two courses and speeds is best.

Problem #2

The true wind is from 320° at 20 knots. Determine the ship's course and speed necessary to create a relative wind of 020°R (20° starboard) at 30 knots.

1. (See figure 11-20) Plot the true wind
2. Looking out from the center, plot dot 1 20° to starboard of the imaginary ship, on the 30-knot circle. (Use the 5:1 scale.)
3. From dot 1, swing a 20-knot arc (true-wind speed) across the true-wind course line.
4. Plot dot 2 at the point where the arc crosses the true-wind course line.

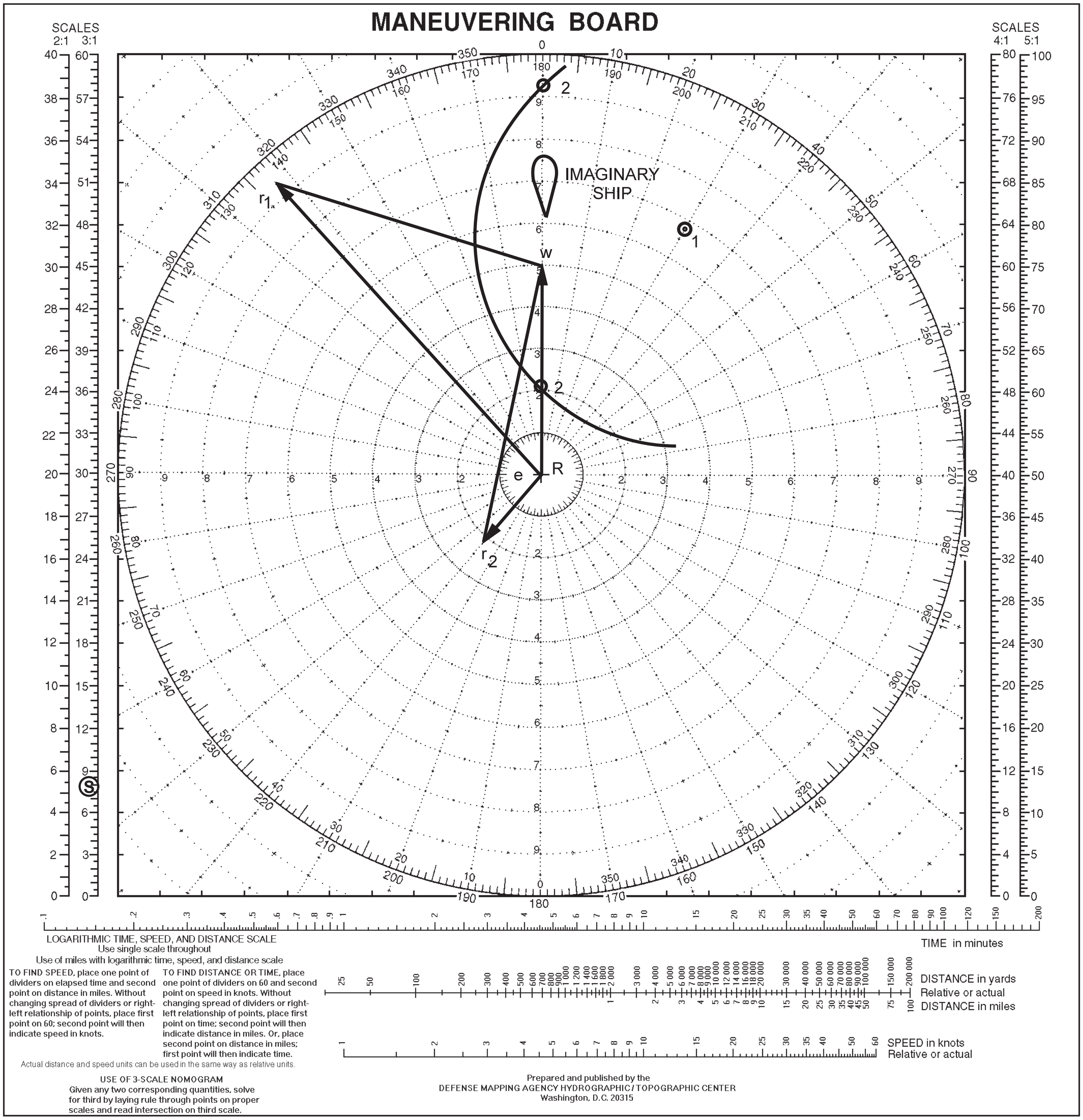

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Figure 11-19.—Desired wind problem #1.

5. Parallel the dot 1-dot 2 line to the center to determine ship's required course.
6. Measure from the center of the board to dot 2 to determine ship's speed.
7. Complete the vector diagram.

In this problem, the two solutions are 289 at 11 knots and 171 at 45.5 knots. Since a speed of 45.5 knots is not practical, we will consider only the first solution.

Check your plot against figure 11-20. Course 289° and a speed of 11 knots are required to obtain a relative wind of 020°R at 30 knots. If you check the *rw* vector

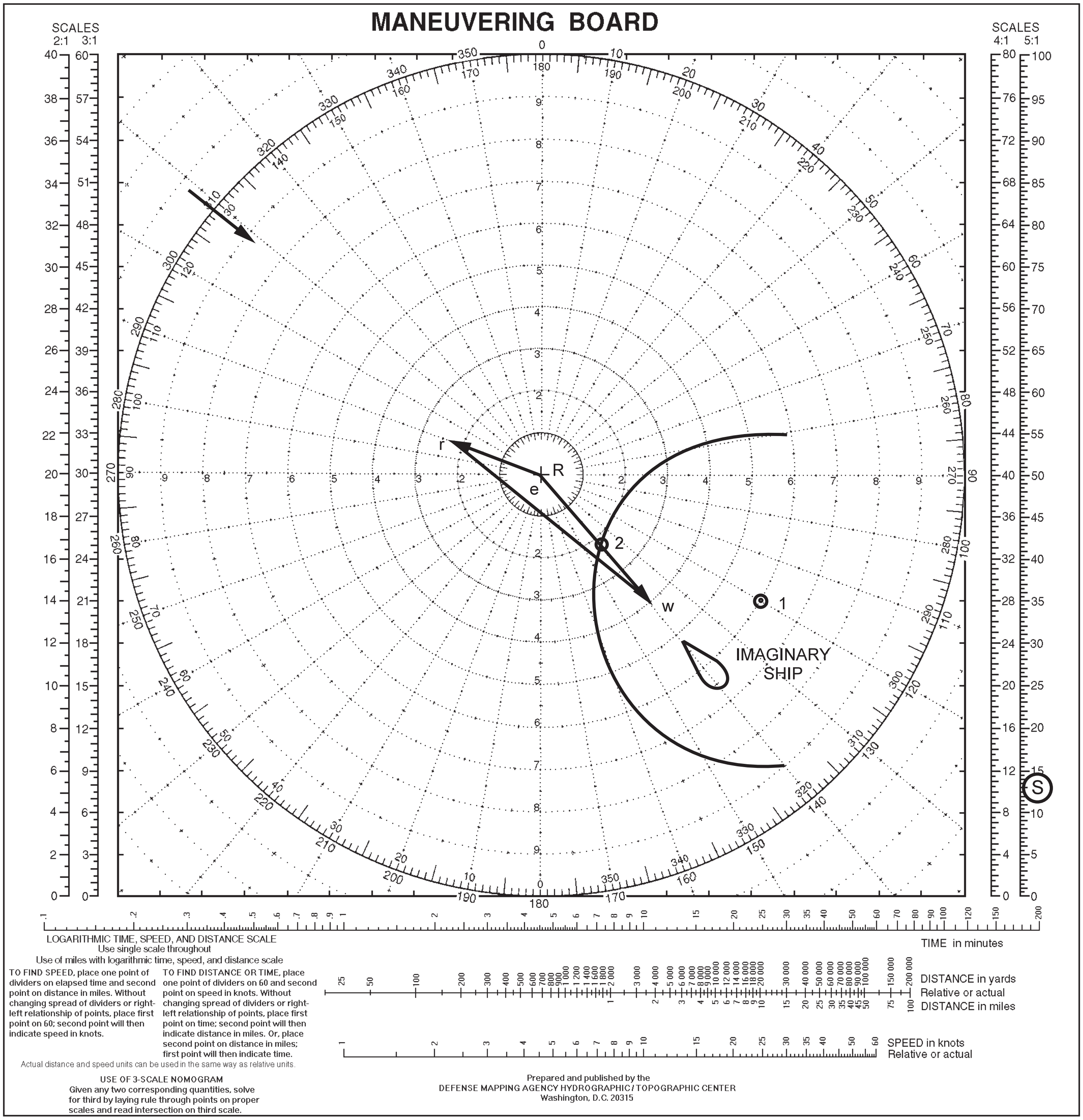

Figure 11-20.—Desired wind problem #2.

direction and length, you will see that the apparent wind is from 309°T (020°R) at 30 knots.

Desired Wind (Alternate Method)

Problem

An aircraft carrier is proceeding on course 240° at 18 knots. The true wind is from 315° at 10 knots. Determine a launch course and speed that will produce a relative wind across the flight deck of 30 knots from 350° relative (10° port). Refer to figure 11-21.

Solution

Set a pair of dividers for 30 knots using any convenient scale. Place one end of the dividers at the origin (*e*) of the maneuvering board and the other on the 350° line. Mark this point *a*. Set the dividers for the true-wind speed of 10 knots and place one end on point

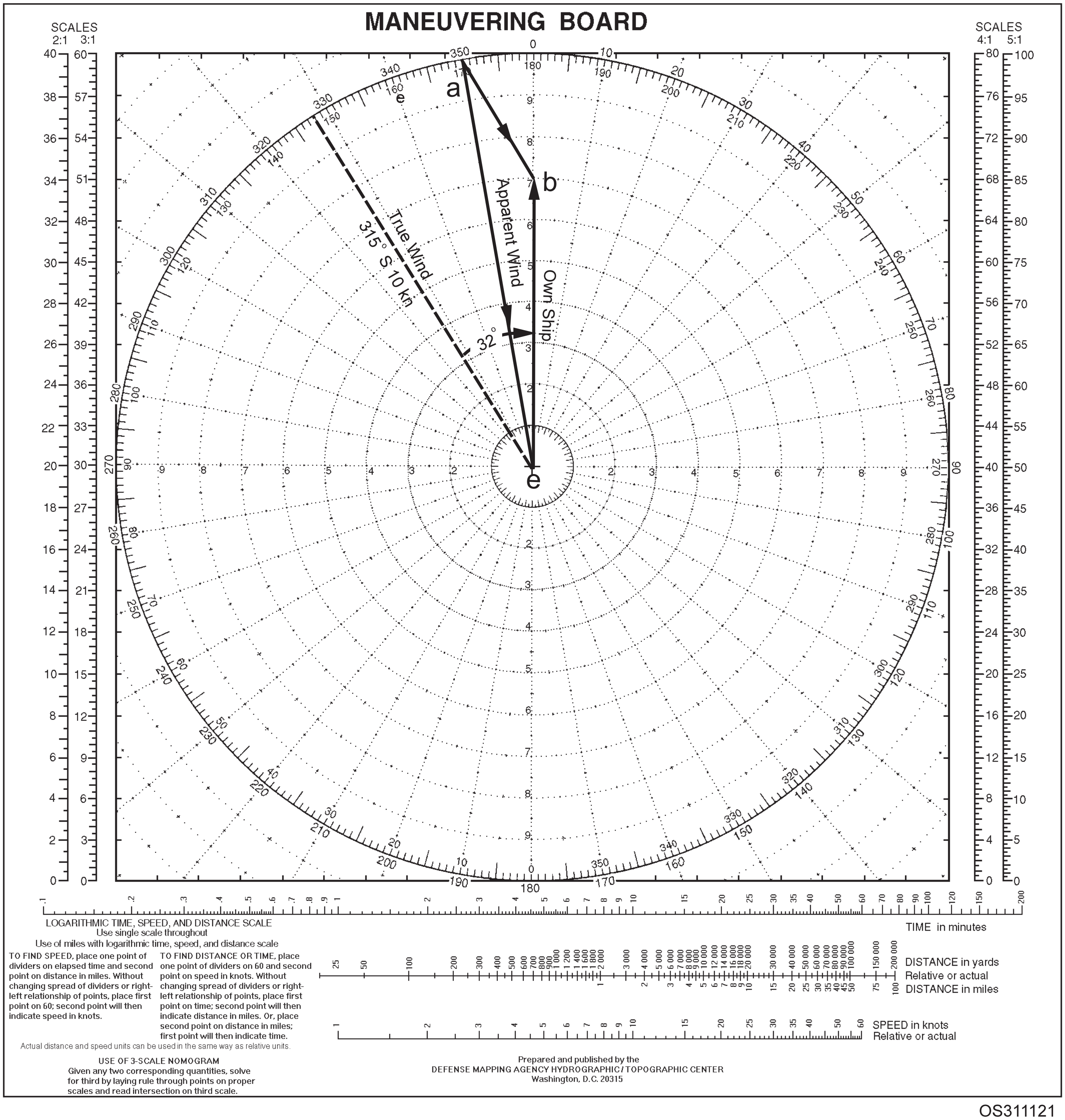

Figure 11-21.—Desired wind (alternate method).

a, the other on the 000° line (centerline of the ship). Mark this point on the centerline *b*. Draw a dashed line from origin *e* parallel to *ab*. This produces the angular relationship between the direction from which the true wind is blowing and the launch course. In this problem the true wind should be from 32° off the port bow (328° relative) when the ship is on launch course and speed.

The required course is 347 (315° + 32°); the required speed is 21 knots.

NOTE

On a moving ship, the direction of true wind is always on the same side and aft of the direction of the apparent wind. The difference in directions increases as the ship's speed increases. That is, the faster a ship moves, the more the apparent wind draws ahead of the true wind.

MANEUVERING BOARD TECHNIQUES

In this chapter, we have tried to show you how to solve basic maneuvering board problems. Now we offer a few hints on how you can avoid making mistakes as you work those problems.

1. Be sure to read the problem carefully; be certain you understand it before you proceed with the solution. Check all of the numbers carefully.
2. Avoid using reciprocals. When a bearing is given, be sure you understand to which ship the bearing applies or from which ship it is taken ("bearing to" or "bearing from").
3. Be particularly careful of the scale of the nomogram at the bottom of the form.
4. Measure carefully. It is easy to select the wrong circle or to make an error of 10° in direction. Read your plotted answers carefully.
5. Plot only true bearings. If a relative bearing or compass direction is given, convert it to a true direction before plotting it.
6. Label all points, and put arrowheads on vectors as soon as you draw them.
7. Remember that DRM and relative speed are the direction and length of the *rm* vector. The direction is always from *r* to *m*.
8. Remember that true vectors always originate in the center of the maneuvering board and that relative vectors originate outside the center.
9. Remember that vectors indicate direction of motion as well as speed. Thus, motion along the relative movement line is associated with relative speed, not actual speed. You can determine relative speed when you know relative distance and time. To obtain actual speed, you must know actual distance and time.
10. Remember that the maneuvering board moves with the reference ship.
11. Do not attach undue significance to the center of the maneuvering board. This point is used both as the origin of actual speed vectors and as the position of the reference ship merely for the sake of convenience.
12. Work a problem one step at a time. An entire problem may seem complicated, but each step is simple, and often suggests the next step. Remember that all problems are based on a few simple principles.
13. Remember to use the same scale for all speeds and to draw all distances to a common scale.

We suggest that you refer to this list periodically, because almost every maneuvering board mistake is based either in violating one of these rules or on making simple arithmetic errors.

ANSWERS TO CHAPTER QUESTIONS

A1. *The motion of one object with respect to another object.*

A2. *In the center of the maneuvering board, labeled as R .*

A3. *The logarithmic scale based on the two of the time, speed, or distance values that you know.*