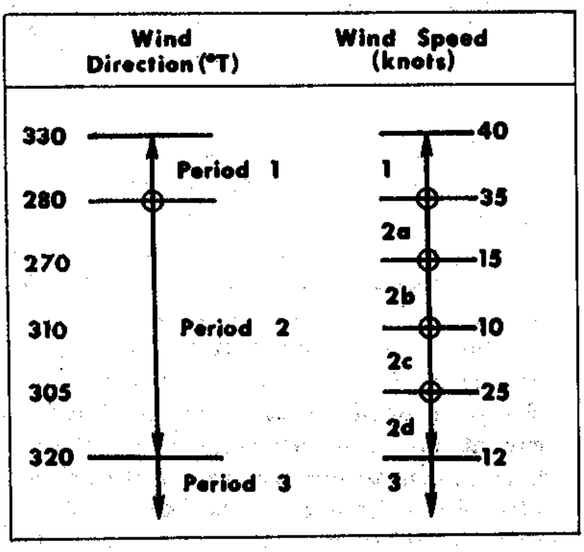
7. Wind Current Example Problem. The following problem is intended to illustrate the various computational procedures described in the previous sections.

Given: Present time is 0000 on the 14th. Information is received that a distress occurred at 0000 on the 13th. Position of the distress is 40°–00′ N, 60°–00′ W. Search is expected to commence at 0800 on the 14th and to be completed by 1600 the same day. The following weather information is obtained:

Day	Time	Wind direction (° T.)	Wind speed (knots)	Fetch (miles)
11------	0000	330	40	750
12------	1200	280	35	200
13------	0000	270	15	400
13------	1800	310	10	600
14------	0000	305	25	800
14------	0600	320	12	200

The first step is to segregate the wind data into periods based upon directional changes and subperiods based on wind speed changes. This may be accomplished by inspection and is shown as follows:



Period 1:

Wind duration = 36 hours
Wind direction = 330° T
Wind speed = 40 knots

WC direction = 330° + 180° + 20° = 530° = 530° − 360° = 170° T

The wind current speed reaches a high of 1.04 knots after its 36 hour duration. Since a change of wind direction greater than 45° occurs at 1200 on the 12th, decay of the current commences at that time. From figure 8–9 we determine that the current will decay to zero over a 48-hour period. For this problem we are only interested in the magnitude of the current velocity between 0000 on the 13th and 1200 on the 14th. By 0000 of the 13th current decay has been occurring for 12 hours. Effective duration is 36 hours, therefore the "Greater than 18 hours" curve of figure 8–9 applies. WC speed = 0 + (1.04) (0.5) = 0.52 knot. Current velocity at the end of the time of interest is WC speed = 0 + (1.04) (0) = 0. The top curve of figure 8–11 represents the growth and decay of this wind current. For cases such as this with large build-up and decay duration identification of current speeds at intermediate times will improve the accuracy of the solution. The mean current speed during the period of interest is computed linearly to be 0.26 knot. The wind current is thus 170° T at 0.26 knot. Since we are interested in the drift effect of the wind current we must convert speed into distance. The wind current generated by this wind acted on the distressed craft for 36 hours. The drift vector is found to be towards a direction of 170° T for a distance of approximately 9.4 miles.

Period 2:

Subperiods	(a)	(b)	(c)	(d)
Wind duration (hours)------	12	18	6	6
Wind direction ° T---------	280	270	310	305
Wind speed (knots)--------	35	15	10	25

Wind current direction for the entire period is based on the mean wind direction. The mean wind direction is computed by weighting the various directions by the duration of their existence. Mean wind direction =

$$\frac{(12)(280)+(18)(270)+6(310)+6(305)}{12+18+6+6} = \frac{11,910}{42} = 284°\text{T}.$$

WC direction = 284° + 180° + 20° = 484°. WC direction = 484° − 360° = 124° T.

The first step in determining current speed is to inspect the wind speed changes for the pur-

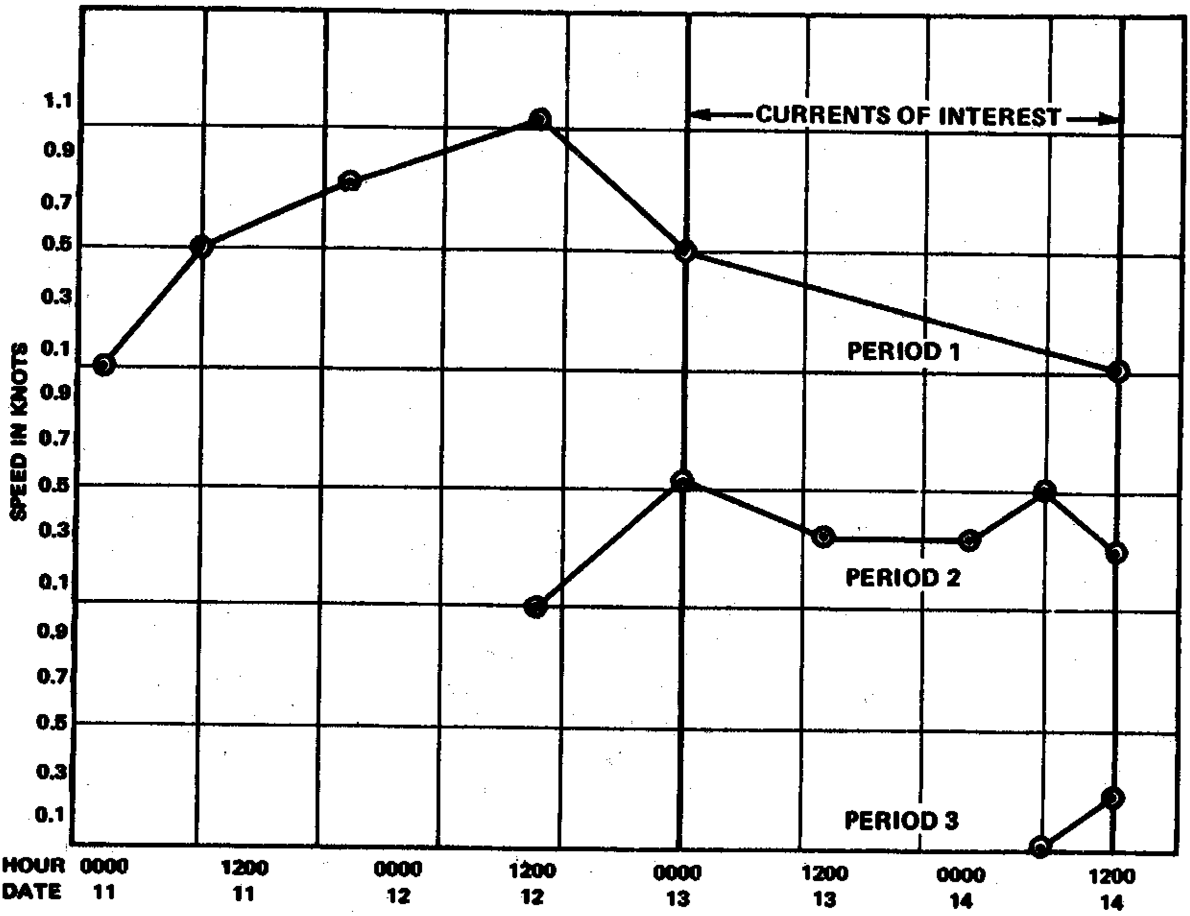


FIGURE 8–11

pose of determining the type of action which should be taken for each speed subperiod. Changes in wind speed equal to or less than 10 knots allow us to combine the subperiods. In this example subperiods 2b and 2c are combined into a single subperiod and the mean wind speed is used.

Wind speed (subperiods 2b and 2c)

$$\frac{(18)(15)+(6)(10)}{24}=\frac{330}{24}\approx 14 \text{ knots.}$$

Period 2a is a build-up period; the current reaches a maximum speed of 0.54 knot, Transition from period 2a to period 2bc requires use of the decreasing speed method. The maximum limiting current supportable by a 14 knot wind is 0.29 knot. The current decay differential is 0.54 minus 0.29 or 0.25 knot. The effective duration of this decay is 12 hours minus 4 hours or 8 hours. Using figure 8–9 decay from 0.54 knot to 0.29 knot requires 12 hours, thus the steady state current of 0.29 knot will exist by 1200 on the 13th. The current velocity will increase when the wind speed changes from period 2bc to 2d. At the time the change starts, 0000 on the 14th the current speed is 0.29 knot. For a 25 knot wind speed the equivalent duration of a 0.29 knot current is approximately 6 hours. This is added to the 6 hours duration of period 2d yielding an effective duration of 12 hours. The current at the end of period 2d is 0.5 knot. A change in wind direction greater than 45° occurs at the end of period 2d. Decay of the 0.5-knot current to zero commences at 0600 on the 14th. From figure 8–9 it is determined that it will take 24 hours to complete the decay. Decay would be complete by 0600 on the 15th. However, we are only interested in current effects up to 1200 on the 14th, therefore the current speed existing at 1200 on the 14th must be determined. Decay time is 6 hours; entering figure 8–9 the decay factor is determined as 0.5. WC speed $=0+(0.5)(0.5)=0.25$ knot. The middle curve of figure 8–11 represents the generation of wind driven current during this period.

The wind current speed during the period of interest for drift effect 0000, 13th to 1200, 14th is 0.36 knot. The drift caused by the wind current of this period is towards 124° T for a distance of 13.1 miles.

Period 3:

Since 1200 on the 14th is the midsearch time, we are only interested in the effects caused by the wind current that was generated during the first six hours of the current's existence.

Wind duration = 6 hours.
Wind direction = 320° T.
Wind speed = 12 knots.

WC Direction = 320° + 180° + 20° = 520°. WC Direction = 520° − 360° = 160° T. WC speed at the end of 6 hours is 0.22 knot. The mean WC speed for the period is 0.11 knot. The drift caused by this current is 0.7 mile in the direction 160° T.

The total drift effect attributable to wind current for this problem is the vector combination of the various periods. Period 1 WC drift is 170° T for 9.4 miles. Period 2 WC drift is 124° T for 13.1 miles. Period 3 WC drift is 160° T for 0.7 miles. The total drift caused by wind driven currents is 144° T for a distance of 21.4 miles. Figure 8-12 is a graphic solution of the vector combination.

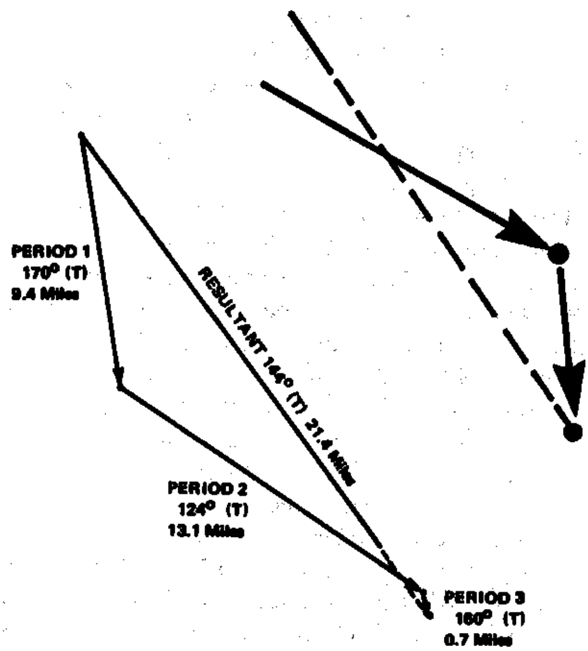


FIGURE 8-12

i. Sea Current (SC)

Sea current is the current present in the open sea that is caused by factors other than local winds. It is the permanent, large scale flow of the ocean waters. Sea current is also called slope current since a cross-sectional view would reveal that the surfaces are actually sloping rather than flat. Sea current is greatest in those areas where major ocean currents are found.

There are several sources for obtaining sea current information. Various atlases and pilot charts will provide historical information. That is, information that has been tabulated over many years and then averaged to obtain generalized data for that particular atlas. This information, called climatological information, will only tell you what the sea currents were in the past—not necessarily what they are at present. However the odds are that existing currents will be similar to their climatological history.

Synoptic charts provide information that is based on the immediately past weather and oceanographic information. If the input data is ample, these charts will provide information on what the existing currents are at the present time.

Some published sources for obtaining sea current information are discussed below. Most of these sources provide historical values of sea current information for use in the *initial* planning stage of a search. Subsequent current information should be obtained by on scene observations whenever possible as discussed in paragraph 814. This latter information has the advantages of accuracy and the fact that it provides a combined wind current and sea current vector. Furthermore, when more accurate initial information is available, it should be used instead of the sources listed below for the initial planning stage. Such information might be obtained from Naval Oceanographic Office computer files, SAR current charts prepared by the Coast Guard Oceanographic Unit for specific areas, other current charts prepared specially for local areas, etc.

1. Section 1 of the Oceanographic Atlas. This document, published by the Defense Mapping Agency, may be used when the publication is available for the area in question. It is preferred over the Atlas of Surface Currents or Pilot Charts. For the current direction, the red and blue arrows on the pages identified as the prevailing surface currents for the season desired are used. Green and black arrows represent relatively unsteady currents which are ignored. Current speed is given on the adjacent plastic overlay pages identified as the mean current speed. Use the speeds given by the nearest contour lines and visually interpolate to the nearest 0.1 knots. For spring and autumn currents, use averages of the direction and speed from the winter and summer charts. In this case the current obtained from a green arrow may be averaged with that from a red or blue arrow.

2. Atlas of Surface Currents. This document, published by the Defense Mapping Agency, is no longer available in those areas for which the Oceanographic Atlas has been completed. In other areas they will have to be used until the issuance of the replacement Oceanographic Atlas. Use the black arrows and numerals (the resultant currents) shown in the one degree quadrangles as the basic figure and note the direction and speed. To determine the current steadiness, use the green arrow from the current rose in the five degree quadrangle which most nearly approaches the direction of the resultant current (black arrow) and compare it with the scale of frequency percentage. If the steadiness is less than 40 percent, the sea current is considered unsteady and should be ignored in drift computations.

3. Pilot Charts. These charts, issued by the Defense Mapping Agency, are published monthly. Select the pilot chart for the body of water, the month, and the year involved. Check the descriptive information on ocean currents and the month. Obtain current direction and velocity from the current arrows displayed on the chart. If the currents in the area under consideration are weak, variable or doubtful, ignore sea current in drift computations. Pilot charts should be used only when no other method is available.

4. Synoptic Charts. Synoptic ocean current charts are prepared by Naval facilities and distributed by Fleet Weather Centers. These charts are still in the experimental stage but, in time may become the most accurate source for ocean currents. Caution must be used with these charts to determine if the current depicted is the sea current, wind current, or a combined, resultant current of both sea and wind currents.

5. Sea Current Use. Sea Current displacement is usually not computed for an incident of less than 4 hours of drift, unless the target is in a relatively high speed current area such as the Gulf Stream.

Sea current will move a floating target in oceanic water areas. Sea current and wind current combine to form the total water current in oceanic areas, for all practical purposes. Oceanic areas are defined as the ocean surface where the influence of tides, coastal rotary currents, and rivers are not predominant. Generally this boundary occurs at approximately 300′ depth of water. However, only local knowledge will provide the SMC with information on how close to the shoreline he should consider sea current to be an influencing drift factor.

j. Tidal Current (TC)

Tides are caused by the gravitational pull of the moon and sun. However, tides are affected by the depth and shape of the sea basin along the coastal areas. In coastal waters, currents will usually be caused by tides and they change in direction and velocity as the state of the tide changes. In some places the tidal currents will be of the reversing type which abruptly change direction approximately 180° at floodtide and slack water. In other places, the direction will change in small increments so as to create a constant rotary current. Variations of these tidal effects may also be found. The exact effect of the tide on currents in any specific area may be found by consulting current tables or current charts. Local knowledge is of great value in dealing with movements of tidal currents. While the changes in direction of tidal currents have a tendency to nullify the cumulative effect, they must be considered in computing drift for the following reasons:

1. Often, with reversing currents, the current effect in one direction is greater than in the other so that, over a period of time, the cumulative effect is more in one direction than the other.

2. Even over short periods of time, the flow of tidal current will cause changes in the probable position of the target for any given search times.

Since most areas affected by tidal currents will be close to land masses, wind current will not usually be a factor in determining drift. Because of this, drift computations will usually depend on the two factors of tidal current (in place of sea current) and leeway.

The cumulative effect of tidal currents may be such as to eventually thrust the target into areas where sea current takes effect. In such cases, water current considerations may shift from tidal current to sea current in the later stages of a SAR case.

k. Lake Current (LC)

Any large lake may have a water current pattern which can vary due to changes in season, weather, time of day, etc. Information on currents existing in lakes usually must come from local knowledge.

l. River Current (RC)

SAR incidents which occur in rivers and in offshore areas near river mouths will be affected by river current.

Tidal currents will affect the river current speeds near the mouths of the rivers. In large rivers this effect may be noticed several miles upstream from the mouth. Published current tables often give values which are combinations of tidal and river flow effects. These are among the areas where reversing currents will be greater in one direction than the other.

On the other hand, river current will affect both tidal current and sea current on the discharge side of its mouth. Some major rivers such as the Amazon extend their influence several hundred miles offshore. Some rivers can have their discharge areas expanded in the spring months when the winter snows run off and upstream spring rains occur.

Most large rivers have data published on their currents. The National Ocean Survey and the Army Corps of Engineers are the most prominent publishers of river current information. Boundaries of discharge areas are usually visible since the muddy river water is contrasted with the cleaner sea water.

When estimating river current in the discharge area assume the current direction is a straight line from the river mouth to the discharge boundary, as shown in figure 8–13. Assume the river current speed decreases linearly from the river mouth to the discharge boundary. The river current speed at the mouth can usually be obtained from published current data, from local knowledge, or by direct observation.

If any type of offshore current is present, the SMC should expect that the river discharge will not fan out symmetrically, but will be displaced in the direction of the offshore current, as shown in figure 8–13B.

River Discharge

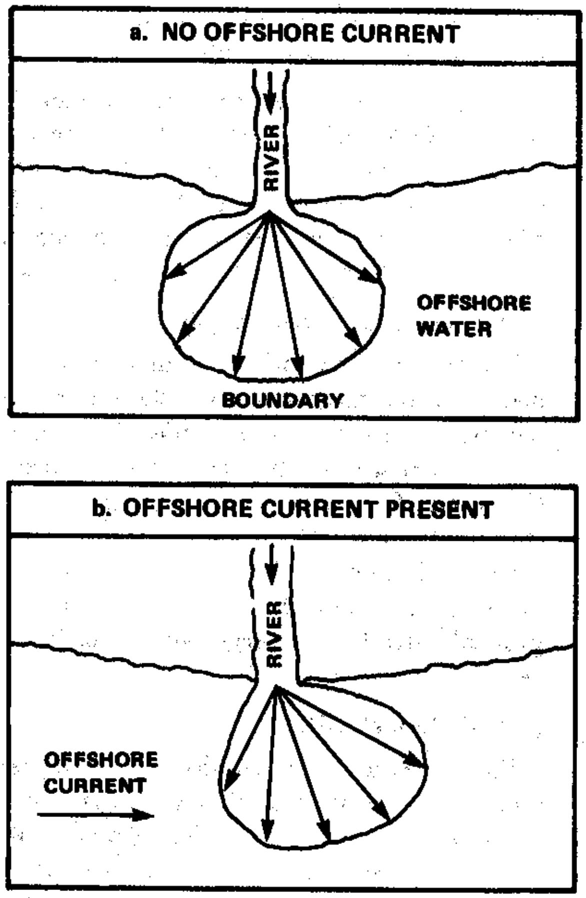


FIGURE 8–13

m. Bottom Current (BC)

Bottom currents must be considered in all underwater incidents. Usually bottom currents are not sufficiently strong to move a sunken object, including a body. However if the bottom current exceeds 4 to 5 knots, as is possible with a rain-swollen flooding river, the possibility exists that the sunken target may be tumbled along the bottom of the river.

In addition, bottom currents will definitely limit the use of divers and submersibles. Divers are limited to about 2 knots of current. Most submersibles have maximum speeds of about 2 to 5 knots.

Bottom current information can be obtained from the Defense Mapping Agency Oceanographic Atlas for certain harbor, coastal, and oceanic areas. In addition, Defense Mapping Agency or Naval Fleet Weather Centers may be able to provide special analysis services for underwater and bottom currents. For bottom currents in harbor areas the U.S. Army Corps of Engineers should be consulted.

n. Long-Shore Currents (LSC)

Long-shore currents are only considered in coastal areas within 1 mile of the shoreline. Long-shore currents are caused by incoming swells striking the shoreline at an angle. Long-shore current information must be obtained from direct observation or local knowledge.

o. Swell/Wave Current (SWC)

When winds are nil, rafts and other small marine search targets may be affected by swells and waves in the area. The effect is similar to leeway in that the raft is being moved through the water. However swell/wave current speed is so small, under 0.1 knot, that this drift force is usually ignored in determining general search areas. It is useful however for determining probable direction of target movement in some cases.

p. Surf Current (SUC)

Surf current is only considered for incidents occurring in coastal surf areas. It is more of a rescue or salvage factor than a search planning factor. Surf currents will move a drifting object after it enters the surf zone. If no long-shore current is present, the surf current will move the object perpendicular to the line of breakers toward the shore. If a long-shore current is present, the object will be displaced simultaneously in the direction of the long-shore current.

Rip current is a special type of surf current. It is a narrow band of current flowing seaward through the surfline. It is a result of the long shore current building up a large volume of water along the beach line, and then this water bursting through the incoming surf, going back to sea. Rip currents are only a few yards wide going through the surfline, but they fan out and slow down after passing the surfline. Rip currents occur when long shore currents are present, and in places where some form of bottom trough, bottom rise, or shoreline feature assists in deflecting the long shore current buildup in a seaward direction.

812 Applying Drift Forces

The drift forces to be applied to any specific incident will depend upon the type of incident, the location, and the information available for estimating the effect of the forces.

813 Plotting Drift Forces

Surface drift forces that act upon the search target are plotted vectorially as shown in figure 8–14A. Since all the drift forces are acting simultaneously on the drifting object, its actual path will be along the resultant drift line. The lengths of the vectors used in search planning are measured in units of distance. In any one solution the same distance scale must be used for all vectors.

Therefore, it should be thoroughly understood that even though some sources give drift information as speeds or velocities, these must all be converted to the distance covered in the same time interval as the rest of the vectors used in that solution.

For example, suppose 4 hours have elapsed since the datum was last computed, and you now want to recompute the additional target drift (displacement). Using the example vectors of figure 8–14A, suppose leeway speed was 0.4 knots, wind current was 0.3 knots and sea current was 0.2 knots. The lengths of each vector would represent 1.6 miles, 1.2 miles, and 0.8 miles respectively (Speed × time = distance). If this were plotted to scale on the search planning chart, it would show the geographical location of $Datum_2$.

814 On Scene Observations

While predicted values for wind and current will most likely be used during initial search planning, every effort should be made to obtain, as soon as possible, on scene observations. These may be obtained as follows:

1. Ships and stations in the vicinity of the incident should be queried in order to obtain the most recent observations of winds. Likewise, if ships in the area are capable of measuring cur-

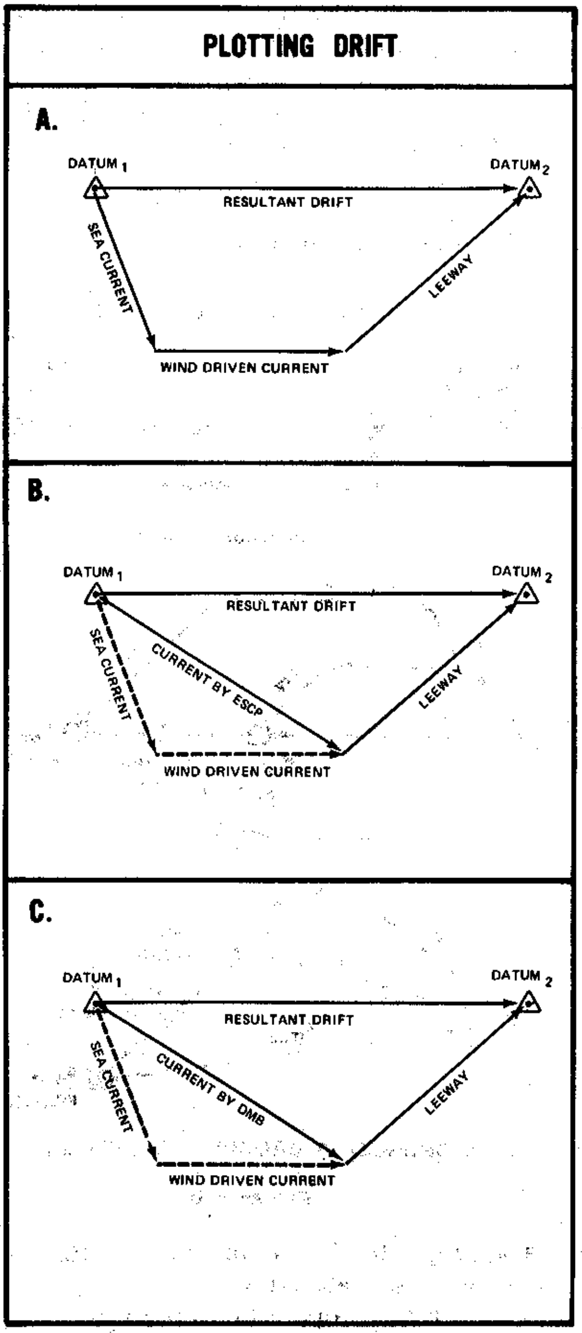


FIGURE 8–14

rent from observations, such observations should be taken and reported.

2. Expendable surface current probes (ESCP) are devices used for measuring instantaneous surface current at the observer's location and are carried by some search and rescue units and some oceanographic units. A probe should be deployed by the first unit which arrives on the scene of the incident in order to obtain an immediate measurement of the surface current. It must be emphasized that current obtained in this manner may not hold true for the duration of the case, and may not hold true for other time periods or locations. This is particularly true in areas affected by tidal current. It should also be noted that the current obtained by means of a probe will be a combination of all surface currents existing in the sea at that location. See figure 8–14B.

3. Datum marker buoys (DMB) are specially designed droppable floating beacons which transmit a signal on UHF frequencies. These buoys are carried by some search and rescue units and the first search unit so equipped arriving on scene should mark datum even if not specifically directed to do so by the SMC. The buoy will then act as a drifting datum point and navigation aid for search aircraft. Since no leeway will exist, the buoy will give an observed value for all surface currents existing in the sea. As the mission progresses the SMC need only apply computed leeway, over the time period from the time of insertion, to the DMB's position in order to obtain a very accurate datum. If subsequent datum marker buoys are deployed, they should be deployed at the newly computed datum in lieu of the previous marker's position. For example, if a datum marker buoy were dropped at $Datum_1$ in figure 8–14C, it would drift along a line to the end of the wind driven current vector. A computed leeway vector would then be added to the datum marker buoy's position after drift, and $Datum_2$ would be the position for dropping the second datum marker buoy.

The DMB will provide an excellent means of measuring the actual sea current existing in the area over the period of its drift. However, when using DMBs in areas of minimal current, the first day's observations may be questionable due to navigational error of the observing platform. The average over two to three days observations will reduce the overall effect of such error. Accordingly, in the long term, it can give a more accurate estimate than other measurements.

As with current probes, it must be emphasized that the current information obtained by a DMB observation should be used with caution. Although the DMB will provide actual current existing at the time of its deployment and subsequent to that time, it will not necessarily reflect the true current affecting a SAR objective during other time periods or in a different location. Caution should also be exercised in utilizing observed drift information if a DMB is used in an area close inshore or in an area known to have diverging current systems within close proximity to each other.

When DMBs are not available to search aircraft, datum should be marked by some other suitable means. ASW aircraft can use sonobuoys for this purpose. If visual markers are used, such as smoke floats or dye markers, datum must be re-marked before the original dissipates and successive re-markings must be made. Another substitute, when DMBs are not available, is to send a surface vessel to datum to act as a "drifter". The search planner must realize that use of a vessel in this manner deprives him of the use of the vessel as a search unit and also that the vessel will have a leeway of its own. The effect of the former must be weighed against the advantages of the drift determination bearing in mind that the area that can be covered by a vessel is small in comparison with that covered by search aircraft.

815 Minimax

Occasionally the information available about the incident is so uncertain that the SMC must make several assumptions to develop a datum point. This problem is overcome by taking all the unknown or uncertain factors and then deciding what their least practical value and their greatest practical value would be.

The *least* practical values of all the unknown variables are vectorially added together. This will provide the minimum distance that the search target should be from the initial position.

The *greatest* practical values of all the unknown variables are vectorially added together. This will provide the maximum distance that the search target could be from the initial position.

The datum point is established midway between the resultant minimum drift position and the resultant maximum drift position. This procedure is called minimax (minimum-maximum) plotting and is shown in figure 8–15.

The minimum drift distance is labeled d_{min}, and the end of the resultant vector is referred to as the minimum drift position. The maximum drift distance is labeled d_{max} and the end of the resultant vector is referred to as the maximum drift position. The datum point is labeled $Datum_{minimax}$.

There are many situations for which minimax

Typical Minimax Plotting

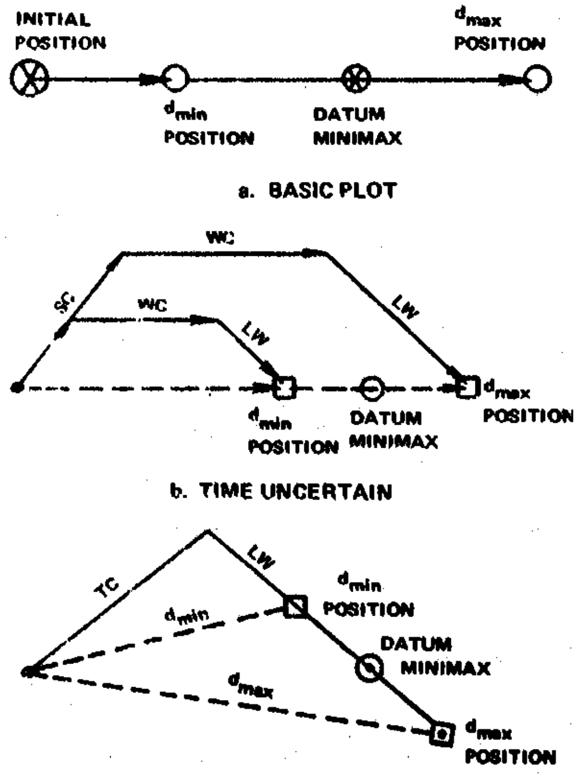


FIGURE 8–15

is appropriate. For example, uncertainty or doubt may exist about the:

(a) Altitude of parachute opening.

(b) Distance a lost child could travel.

(c) Length of time a marine craft has been adrift.

(d) Leeway direction and/or speed.

(e) Time local winds shifted.

(f) Direction and/or speed of water currents.

(g) The distance of an incident unknown although direction is known (e.g. a flare sighting).

Several of the uncertain variables may be inter-related. As an example, a boat may go out to fish and not return at dark. There will be uncertainty as to whether the boat went adrift early in the day or late. The earlier it actually went adrift, the farther it drifts. Next, doubt may exist as to the leeway. A boat will drift much faster without a sea anchor or drogue, but the planner has no way of determining if a sea anchor or drogue is being used. Therefore, two leeway values are possible. Lastly, doubt mav exist as to the wind and current. Here the planner must determine a minimum and a maximum probable wind and current. The wind in turn will affect the leeway. With all these minimum and maximum probable values obtained or estimated, the planner may want to use a minimax solution for a $\text{Datum}_{\text{minimax}}$.

Figures 8–15b and 8–15c depict some typical situations in which time or leeway may be uncertain.

816 Datum and Search Craft Errors

a. Total Probable Error (E)

After determining the datum, an analysis must be made to determine how much error might exist in that datum. In addition, the search planner will also consider a future possible error that could be caused by the search units during the search. All of these possible individual errors are then considered together to determine the total probable error (E). This is accomplished by using a basic statistical method which says that if all the possible individual errors are squared and then added together, that sum will equal the square of the total error ($E^2=a^2+b^2+c^2+\text{etc.}$). In search planning, anywhere from none to three individual errors may be considered.

Determining the total probable error is one of the most important calculations that the SMC must make. The size of the area that will have to be searched depends upon E. The greater the error, the larger the search area.

There are three basic errors that must be considered. These are:

1. Total drift error (D_e).
2. Initial position error (X).
3. Search craft error (Y).

The basic formula for total probable error is thus:

$$E=\sqrt{D_e^2+X^2+Y^2}$$

There is no easy way to accurately determine these values, and each case must be evaluated separately. A careful examination of the factors involved in each variable will, however, afford the planner a basis for his estimate.

b. Individual Drift Error (d_e)

Individual drift error is the error developed during computation for individual drift between two datums for a specified time interval (t).

There are several assumptions and generalizations made when developing a datum in order to keep the required computations practical and simple. In addition, the data source publications themselves have generalized information. In order to account for these and other possible errors in datum, one-eighth of the total drift is assumed to be the drift error. Another way of looking at this is, for every 8 miles an object is computed to have drifted it could be up to 1 mile ahead, behind, or on either side of the 8 mile point. As a practical matter this assumption has been reasonably verified over many years of search planning. Thus if a target had drifted 48 miles, its drift error is assumed to be 6 miles (48 divided by 8=6). This method of computing drift error is used only when a single set of conditions can be used to determine drift, and a minimax solution is not required.

Individual drift errors are possible when computing any kind of drift. Aerospace-trajectory drift, parachute drift, sinking drift, and water drift all have errors. However, all individual drift errors are ignored if less than one mile. This, in effect, leaves only water drift that must be considered. If by any chance there are more than two kinds of drifts each over 8 miles (e.g. $d_P=16$ and $d_e=24$) then the drift error for that time interval could be found by the addition of the individual errors. In the above case this would be 2+3=5. However, this occurs so rarely that most search planners automatically ignore errors for aerospace-trajectory drift, parachute drift, and sinking drift, and only consider water surface drift errors.

c. Minimax Drift Error

When a minimax solution is used to find the datum point, a modification of the above procedures is required to find the drift error. This is accomplished by two methods:

1. Graphical solution.
2. Algebraic solution.

The graphical solution is depicted in figure 8–16, d_e is found for both d_{min} and d_{max} by dividing their distances by 8. Using the d_{min} position as a center, and the minimum d_e as a radius, a circle is drawn. Using the d_{max} position as a center, and the maximum d_e as a radius, another circle is drawn. A third circle is now drawn in such a way as to be externally tangent to the other two circles and with its center located on a straightline connecting the d_{min} position and the d_{max} position. The radius of this circle is the minimax drift error $d_{e\ minimax}$). This is used as D_e.

It should be noted that the 3 circles need not actually be drawn when solving for $d_{e\ minimax}$. Once the d_{min} position and d_{max} position have been determined, the remainder of the problem can be laid off on a line joining the two positions, if the line is extended in both directions.

An algebraic method can be developed to obtain $d_{e\ minimax}$. First plot the minimum and maximum positions. Then measure the distance between the two.

$$\text{Then } d_{e\ minimax} = \frac{\text{Distance} + d_{e\ min} + d_{e\ max}}{2}$$

Suppose a small boat fails to return from a day of fishing. The operator was known to have been planning to fish in the vicinity of a sea buoy and was last seen there 12 hours before he was due to return home. A hypothesis is made that he broke down in that area sometime during the 12 hour period. Using the latest time of probable casualty, the minimum drift distance is found to be 30 miles. Using the earliest time of probable casualty the maximum drift distance is found to be 86 miles. There is no appreciable difference in direction of drift. Plotting the minimum datum and maximum datum and solving graphically, the minimax drift error is found to be 35.3 miles. Using the algebraic solution above gives the same answer.

d. Total Drift Error (D_e)

The precise definition of Total Drift Error (D_e) is the arithmetic sum of all the individual drift errors accumulated during a mission, for the elapsed time since the search object was first exposed to the external forces causing drift movement, to the time of the latest computed datum. From this definition it should be noted that:

1. Individual drift errors must always be computed between each datum.

2. Individual drift errors (d_e) are added arithmetically when new, updated datums are computed.

3. Individual drift errors are not added vectorially.

Minimax Drift Error—Graphic Solution

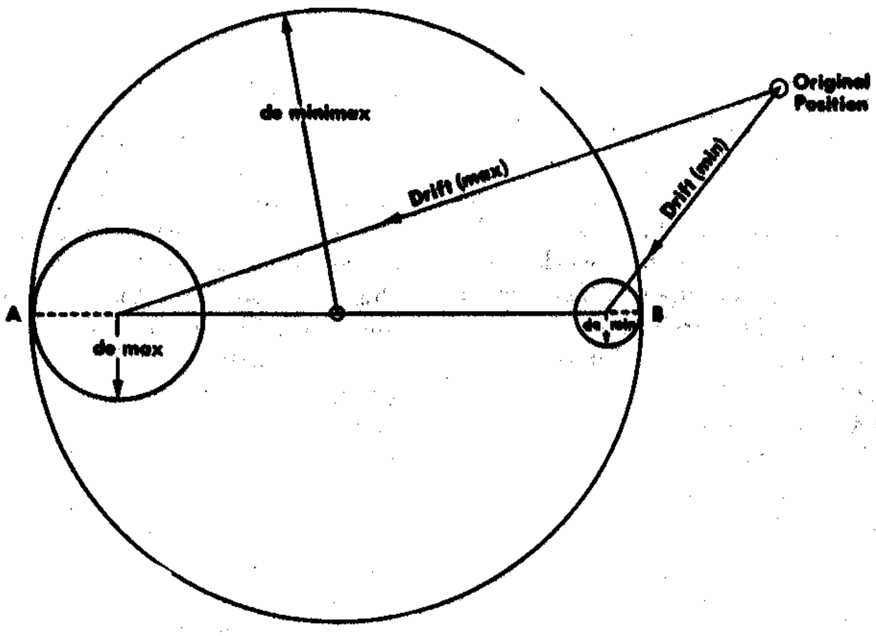


Figure 8–16

D_e is used when determining total probable error (E). When the first datum is computed after establishing an initial position, d_e will usually equal D_e. However as the mission progresses another datum will be computed. D_e will then be d_{e1} plus d_{e2}; and so on. This method is correct for all situations except when minimax plotting is used to account for uncertainty in direction. The addition of drift errors which have been determined from a series of minimax drift datums causes an arbitrary enlargement of total drift error. When using minimax for directional uncertainty, minimax D_e must be determined for the final datum position only.

e. Initial Position Error (X)

Initial position error is the assumed error of the initially reported position of a SAR incident. This error is based on the navigational accuracy of the distressed craft, or a position fixing accuracy of the radio direction finding net, radar net, sofar net, etc. that reported the initial position.

Figure 8–17 lists the navigational fix errors (Fix_e) which are assumed for positions reported as fixes by various types of craft.

The differences between the various craft are based on the type and sophistication of the navigation equipment typically installed in them. For example the typical light aircraft or jet aircraft with only one engine will have only a minimum of navigation capability. Hence its assumed fix error is larger than a multiengine aircraft. The search planner should realize that both fix error (Fix_e) and DR error (DR_e) discussed next, are only guide lines. He may alter them as he desires, should he have information indicating that the navigational capability of the craft is substantially different from the typical.

When the initial position is reported as a fix, the initial position error is the fix error ($X = Fix_e$).

When the initially reported position is based on dead reckoning (DR) navigation, an additional error is possible for the distance traveled since the last fix was obtained. Figure 8–18 lists the navigational DR errors (DR_e) which are assumed for DR positions reported by various types of craft.

When the initial position is reported as a DR position, the initial position error is the sum of the fix error and DR error.

Navigational Fix Errors

Type of craft:	Fix_e
Vessel	5-mile radius.
Submarine (military)	Do.
Aircraft with over 2 engines	Do.
Aircraft with only 2 engines	10-mile radius.
Aircraft with only 1 engine	15-mile radius.
Submersible	Do.
Boat	Do.
Position fixing net	As classified by net.

FIGURE 8–17

Navigational DR Error

Type of craft:	DR_e
Ship	5 percent of DR distance.
Submarine (military)	Do.
Aircraft with over 2 engines	Do.
Aircraft with only 2 engines	10 percent of DR distance.
Aircraft with only 1 engine	15 percent of DR distance.
Submersible	Do.
Boat	Do.

FIGURE 8–18

f. Search Craft Error (Y)

The SMC must also consider errors that will be introduced by search craft. These are errors which are based on the navigational accuracy of the search craft, and applicable any time a search craft is locating a datum, a commence search point, or executing a search pattern. In other words anytime the search craft is in the search area. All search craft are expected to maintain frequent and near-continuous navigational fixes while conducting their search. Therefore only fix errors are applied for search craft; DR errors should be negligible. If a search craft must resort to DR navigation in the search area, it should always advise the SMC. The SMC must then use both Fix_e and DR_e for determining search craft error. In such a case $Y = Fix_e + DR_e$.

The same values for Fix_e (and DR_e if required) as applied to distressed craft also apply to search craft. Therefore figures 8–17 and 8–18 are also used for search craft error.

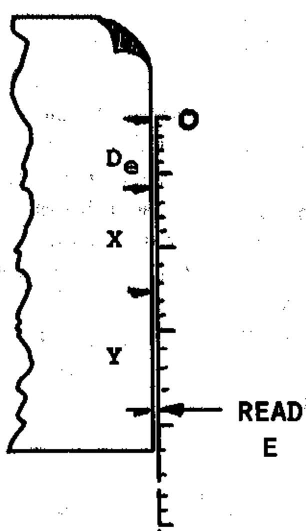
g. Total Probable Error Solution

The total probable error scales in figure 8–19 are provided to eliminate the need for search

TOTAL PROBABLE ERROR

$$E = \sqrt{D_e^2 + X^2 + Y^2}$$

1. On the edge of a piece of paper make two marks defining the length O to D_e, as measured against Scale I.
2. Move the second mark up to Zero on Scale I and make a third mark defining the length O to X.
3. Move the third mark up to Zero on Scale I and make a fourth mark defining the length O to Y.
4. Place the first mark against Zero on Scale I and read E directly at the fourth mark.
5. If the fourth mark extends beyond the range of Scale I, repeat the entire procedure using Scales II or III.



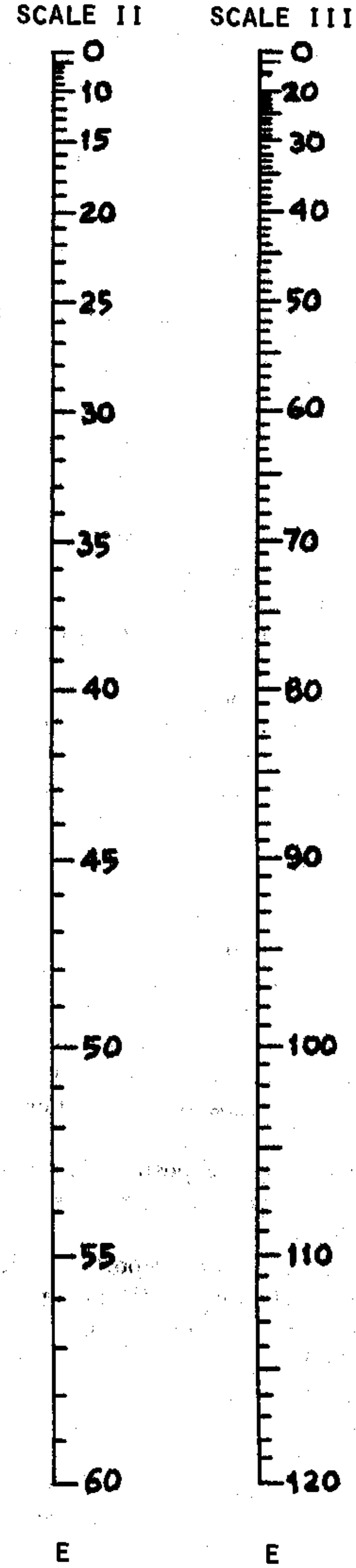


FIGURE 8-19

planners to square a number, add the squares, and then figure out the square root of the sum. Thus the basic error formula can be manually solved in about 30 seconds with sufficient accuracy for SAR operations. Figure 8–19 is based on the statistical "sum of the squares" concept and is self explanatory. With a little practice the solution can be worked rapidly with a pair of dividers. Thus, it will solve either of the following total probable error (E) formulas which may apply to various circumstances.

1. $E=\sqrt{X^2+Y^2}$

2. $E=\sqrt{D_e^2+X^2+Y^2}$

Formula No. 1 is used in the initial hours (up to 4) of a mission when drift can be disregarded, and in most inland missions.

Formula No. 2 is used in missions when drift forces are a factor.

h. Total Probable Error Examples

A light, single engine aircraft flying on airways overland makes a routine position report over Panhandle City. His outbound track is 180° T on the airway, his altitude is 3,000 feet, and he is making good a ground speed of 100 knots. Winds aloft are nil, surface to 7,000 feet. 30 minutes later the pilot broadcasts a MAYDAY, and reports his engine is on fire, he is bailing out, and nothing more.

The SMC assumes parachute opening altitude is 3,000 feet. Since winds are calm, d_e is zero, and his aerospace position and his surface position are the same. He is over land so no other drift forces will apply. His aerospace position is computed by the SMC using the position report over Panhandle City as a fix, and subsequent movement by DR navigation. The aircraft's DR distance is 50 miles (30 minutes times ground speed=50 miles). The aircraft's position is thus 50 miles 180° T from Panhandle City. Single engine aircraft will be used for search.

Datum is established 50 miles 180° T from Panhandle City. Initial position error has both Fix_e of 15 miles (fig. 8–17) and DR_e of 7.5 miles (fix. 8–18) so that X=22.5. Search craft error has only Fix_e of 15 miles (fig. 8–17). Therefore, total probable error is:

$$E=\sqrt{X^2+Y^2}$$

$$E=\sqrt{(22.5)^2+(15)^2}$$

$$E=27 \text{ (fig. 8–19)}$$

As another example, suppose a vessel is sinking at a reported fix, crew is taking to liferafts and 4-engine search aircraft will arrive on scene 3 hours later. Life raft drift is computed to be 16 miles by the time the search aircraft arrive.

Total drift error:

$d_e=\frac{1}{8}\cdot 16$ miles $=2$ miles

Therefore,

$D_e=2$

Initial position error:

$Fix_e=5$ miles

$DR_e=0$

Therefore

X=5 miles

Search craft error:

$Fix_e=5$ miles

$DR_e=0$

Therefore

Y=5

Total probable error:

$$E=\sqrt{D_e^2+X^2+Y^2}$$

$$E=\sqrt{(2)^2+(5)^2+(5)^2}$$

$$E=7.8 \text{ miles (fig. 8–19)}$$

i. Changes in Total Probable Error

1. Drift Changes. As a mission progresses, a search target in a water area will be continually drifting. This requires the SMC to periodically recompute datum. As a general rule datum is recomputed every 4 or 6 hours in these circumstances. When there are no uncertain variables, minimax is not used. Assuming this situation, suppose a surface position was established using the initially reported fix as the surface position. Drift was zero; drift error was zero, Datum was computed 4 hours later, and $d_1=16$ miles, $d_{e1}=2$ miles. At this time, $D_e=d_{e1}=2$ miles. Six hours later $Datum_2$ is computed and $d_2=24$ miles, $d_{e2}=3$ miles. At this time $D_e=d_{e1}+d_{e2}=2+3=5$ miles. The process continues throughout the rest of the mission.

Total drift error, D_e is obtained by arithmetically adding the individual drift errors, d_e, between each datum, and treating them on an accumulating basis.

When minimax plotting is required, the new minimum and maximum positions are plotted, and a new minimax D_e is found by graphic solution or algebraic formula.

2. Search Craft Changes. The SMC recomputes E each time the type of search craft is changed, if the different types of search units have different fix errors.

3. Initial Position Changes. Once the errors in the initial position are computed, they will not change as the mission progresses, unless later information shows initial assumptions to be in error.

817 Datum Line

So far we have only looked at the position-known situation in which a datum point could be established. However, if only the proposed track of the distressed craft or person is known, a datum line must be established. The proposed track is first plotted. Then a series of DR positions are computed for the distressed craft's estimated progress along the track. The DR positions at each end of the track are always used. Turning points along the track at which the craft planned to alter heading are also used. If the track legs are long, intermediate DR positions are computed. For aircraft a DR position at least every 5 degrees of latitude or longitude is recommended. For marine craft, a DR position at least each 24 hours along the track is recommended. For lost persons in inland areas, a DR position at least every 4 hours along the track is recommended. The drift time periods associated with each point vary. If the distressed craft became disabled close to its destination, the drift period at this point would be less than that which occurs if the craft became disabled early in the voyage.

Having computed a sufficient number of DR positions, the SMC next treats each DR position as though it were a position-known category. The positions are corrected for any drift that the craft would have been subject to had he broken down, executed bailout, abandoned ship, or experienced a similar mishap at the exact time he would have been at the DR position. Drift is applied to all the DR positions for the length of time adrift up to a common single time, such as the mid-search time.

Thus a series of datum points are developed, one for each DR position. When this is completed, all the datum points are connected by straight lines in sequence. This is the datum line. In effect we have assumed that if the craft experienced a mishap anywhere between our selected DR positions, his drift, up to the common single time, would place him on the datum line.

In summary, a datum line in this case is a known proposed track that has been corrected for drift.

Each of the datum points developed from the selected DR positions are then analyzed for possible errors. The total probable error of each is then computed.

818 Datum Area

When neither a position nor a proposed track is known, a datum area must be developed. Basically, the aircraft glide area depicted in figure 8–1 is a datum area, since the aircraft could be anywhere within that area with equal probability. In a similar approach, a maximum possibility area can be developed by the SMC. For example suppose an aircraft had 3 hours of fuel, the winds at his altitude were 180/15, and all that was known was the airport of departure which was 4 hours ago. The SMC knows he is down somewhere, but where? With some detective work, the SMC determines that the aircraft concerned cruises at 90 knots true air speed. Therefore he knows the aircraft could travel as far as 270 miles (3 hours fuel times 90 knots=270 miles) in any direction while in the air mass. However the air mass is being displaced to the north at 15 knots (winds 180/15). Thus in 3 hours the air mass could be displaced 45 miles (3 hours fuel times 15 knots=45 miles) to the north.

First the SMC plots a vector 000° T, 45 miles from the departure airport. Then he draws a circle, centered on the end of the vector, using a radius of 270 miles. The area within this circle is the maximum possibility area.

Figure 8–20 depicts the general method used to find a maximum possibility area, that is: the maximum possible area in which the search target might be located.

A similar approach can be applied to marine craft using their fuel endurance in hours, maximum range cruising speed, and water drift forces.

Obviously maximum possibility areas can be enormous in size when long range aircraft and

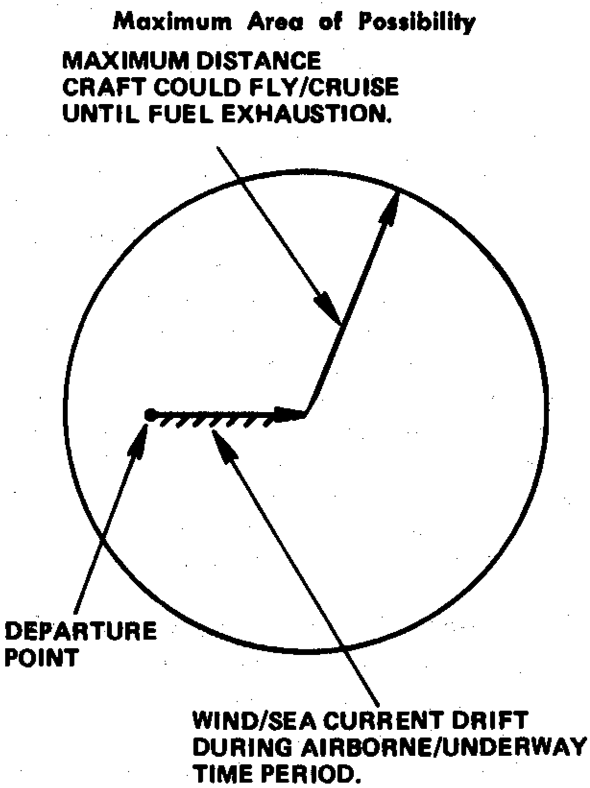


FIGURE 8–20

vessels are the distressed craft. Extensive detective work is always required in these situations in order to reduce this size to a reasonable search area. The search planner may have to depart from the rules given previously and outline the search area based on other hypotheses. For instance, a military aircraft may be reported missing while flying in a defined operating area; a fishing vessel may have gone to particular fishing grounds; a private aircraft or pleasure boat may be known to have intended operating in a general area; a yacht may have been on an extended coastal or ocean cruise. In some cases the datum area will be readily apparent. In others, the area can be narrowed by communications checks and deduction. In still others, the planner can only plan to search large general areas as well as he can.

820 SEARCH AREAS

After establishing datum and finding the total probable error, or errors, the area to be searched must be determined.

Initially, the search must be large enough to insure, at least, a better than 50 percent chance that the target is in the area. This is the purpose of finding the total probable error. By definition of probable error, there should be a 50 percent chance that the target is within a distance of the total probable error from a point datum. A circle with a point datum as a center and the total probable error as a radius would then give an area in which there was a 50 percent probability that the target was located. It would be desirable to increase this radius to the point where the probability would be increased to a much higher value. Expansion of the search area however may result in the following undesirable results which are interrelated:

(a) Decreased probability of detection because of increased track spacing required.

(b) Increased search craft hours required which may not be available.

(c) Increased time required to locate the target because of dilution of search effort.

Prudence dictates that when an incident is in the distress phase, a maximum effort search should be conducted. The aim is to include the most probable location of all survivors in the initial search area and use all available facilities in order to thoroughly search it in the shortest possible time with the highest feasible probability of detection.

In some cases where a search is started during the alert phase, such as cases of overdue surface craft, a planned buildup of effort is more appropriate. As time passes in a planned buildup, the basic area of 50 percent probability becomes progressively larger due to increasing drift and the area itself becomes displaced due to drift. These factors must be taken into account in planning subsequent search areas.

821 Search Radius (R)

Search radius (R) is the radius of a circle centered on a datum point, having a length equal to the total probable error (E) plus an additional safety length to insure a greater than 50 percent probability that the target is in the search area. On land surface, and underwater searches, R is measured in yards; on other searches, R is measured in whole nautical miles. The radius length is increased after each successive search is completed. Search radius is computed by multiplying total probable error by the search safety factor ($R=E \cdot f_s$). Figure 8–21 tabulates the safety factors which are used sequentially to gradually enlarge the search area.

The radius for each search will thus be larger than for the preceding search until a radius 2.5 times the total probable error is reached on the fifth search. Note that the safety factor is, in effect, providing search radii which are 110 percent of E for the first search, 160 percent of E for the second search, 200 percent of E for the third search, etc. This gradually increases the probability that the target is in the search area.

Figure 8–22 summarizes the definitions of search radius as used by the SAR System.

Safety Factors and Search Radius

Search	f_s	R
1st	1.1	1.1E
2d	1.6	1.6E
3d	2.0	2.0E
4th	2.3	2.3E
5th	2.5	2.5E

FIGURE 8–21

Search Radius Definitions

R Search radius, $R=(E)(f_s)$

R_1—The computed search radius for first search effort.

R_2—The computed search radius for second search effort.

R_3—The computed search radius for third search effort.

R_4—The computed search radius for fourth search effort.

R_5—The computed search radius for fifth effort.

FIGURE 8–22

If a considerable time interval occurs between searches, the Total Probable Error will have to be recomputed before each search to take into account the increased drift error that has occurred between searches.

In order to eliminate the need for search planners to manually multiply E by f_s, the nomograph in figure 8–23 has been developed. Line up a clear plastic straightedge with the values of E and f_s, and read the search radius direct from the third scale.

822 Search Area—Stationary Datum Point

Having computed the search radius the SMC then draws a circle around datum with the search radius and usually squares it off with tangents. The area enclosed is the basic search area. After each search area is completely searched, the next search area is computed using the next f_s, and then the new, enlarged search area is searched. The effect of this procedure is to keep researching the original search area while expanding the outer edges successively.

Theoretically the best search area is a circle centered on datum. However only a few search patterns are adaptable to circular search areas. For most patterns, a square or rectangular search area is more practical. Therefore, the basic circular areas are simply boxed-in as shown in figure 8–24. Each side of the square area is twice the search radius in length.

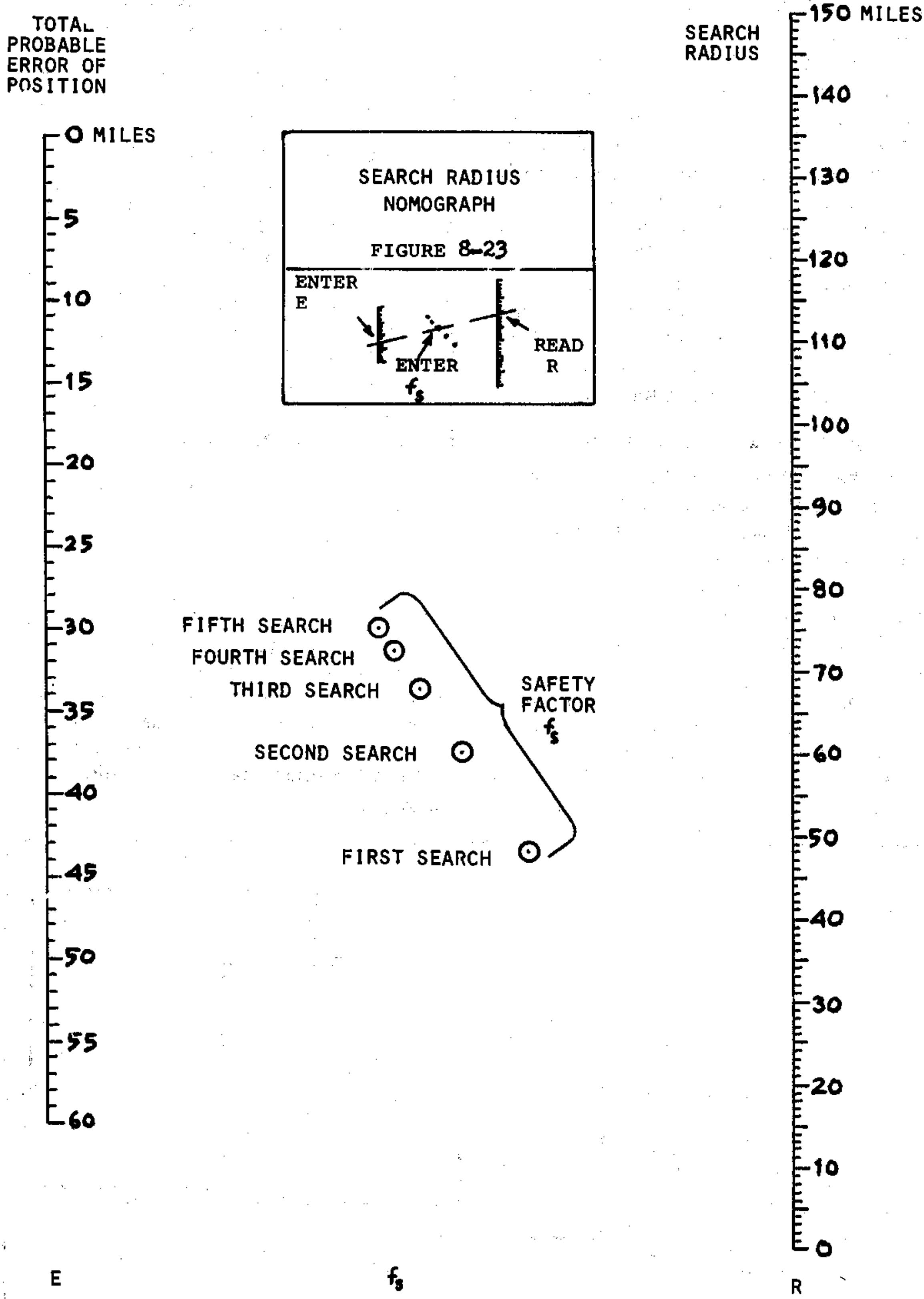
823 Search Area—Moving Datum Point

The datum is almost always stationary for inland incidents. On the other hand it is almost always moving for maritime incidents. Figure 8–25 illustrates the latter situation. The drift in the figure is greatly exaggerated for illustrative purposes. The SMC treats the enlargement of search areas for a moving datum point exactly as he would for a stationary datum. He uses the appropriate search radius with its datum point to draw his search area circles. He then boxes-in the circles if required.

By following this approach, the SMC keeps re-searching the water surface area within which the survivors are most likely to be. The datum movement reflects the drift of the survivors or distressed craft. Therefore by the end of successive searches, all of the previous searches have in effect been centered on the last computed datum. The original area, within which survivors were most likely to be, has been searched 5 different times if 5 searches have been conducted.

824 Search Area—Datum Line

When the circumstances require the development of a datum line, the required search area is easily developed. Remember that we established specific DR positions along the known trackline (para. 817), and then computed drift for each DR position. This gave us several


TOTAL PROBABLE ERROR OF POSITION
0 MILES
5
10
15
20
25
30
35
40
45
50
55
60
E
SEARCH RADIUS NOMOGRAPH
FIGURE 8-23
ENTER E
ENTER f_s
READ R
FIFTH SEARCH
FOURTH SEARCH
THIRD SEARCH
SECOND SEARCH
FIRST SEARCH
SAFETY FACTOR f_s
f_s
SEARCH RADIUS
150 MILES
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
R

datum points, which we then connected to form our datum line. We then computed E for each datum point. To develop our search area, we multiply the safety factor (f_s) times the total probable error of each datum point to get our search radii. We treat each datum point separately and draw circles around each, using their own search radius. Tangent lines are then drawn from circle to circle to establish the lateral boundaries of the search area. The ends of the area are squared off with tangent lines. This procedure is illustrated in figure 8-26. Figure 8-27 shows the development of the next enlargement of the search area, assuming the datum line is in a water area and not stationary.

825 Search Area—Datum Area

When the incident is such that only a datum area exists, search areas may have to be developed differently than described heretofore.

If the area is small, as it would be in the case illustrated in figure 8-1, a search radius should be computed as before and added to the radius of the datum area in order to strike off a search area.

If the area is of reasonable size for search with a high probability that the search object is within it, the Datum Area should be used as the first search area. An example of this case is that where a military aircraft disappears in a prescribed operating area.

If the original datum area is too large for search by available forces, a hypothesis must be developed on what probably happened, and the area must be reduced accordingly to one which can be searched. Clues obtained during the progress of the SAR effort may make it possible to reduce the original datum area to one of the other situations previously discussed.

Search Areas—Stationary Datum Point

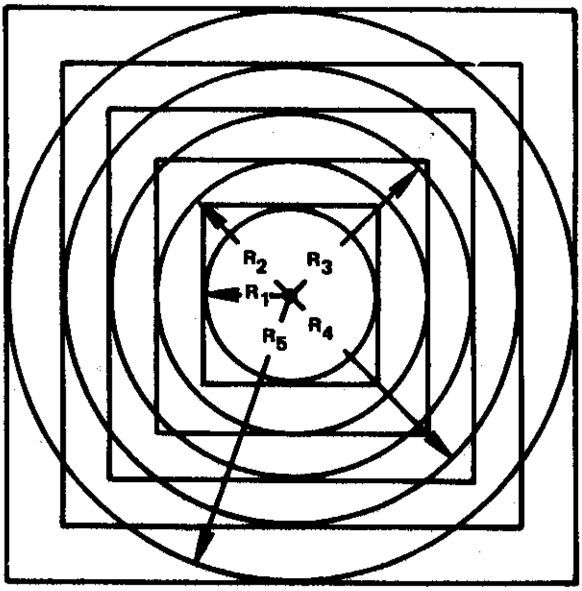


FIGURE 8-24

Search Areas—Moving Datum Point

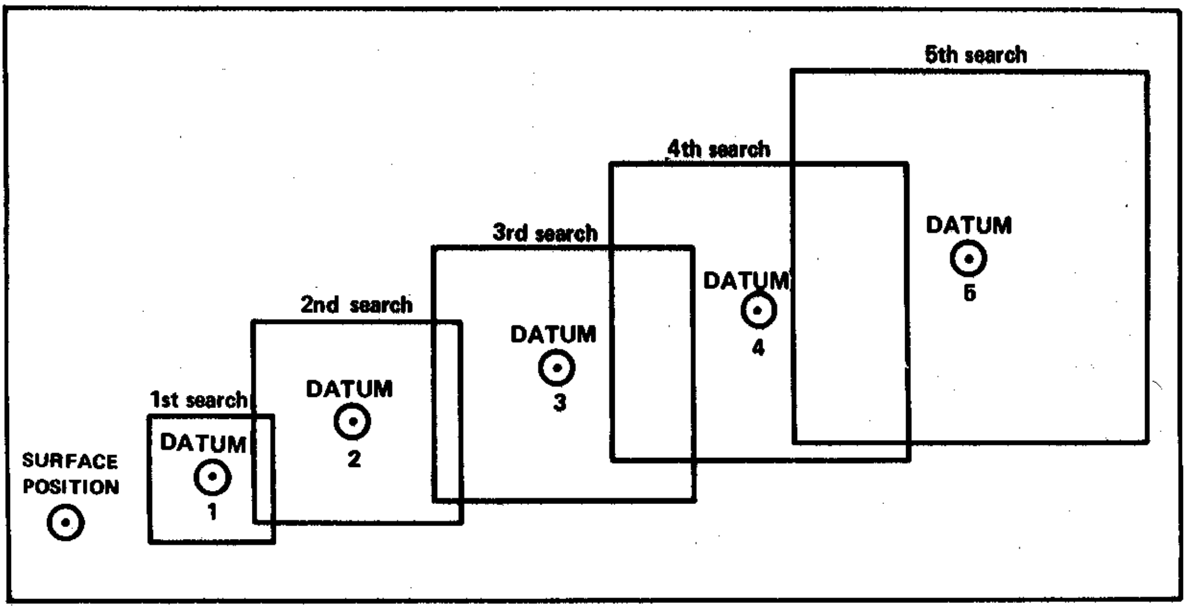


FIGURE 8-25

Search Area—Datum Line

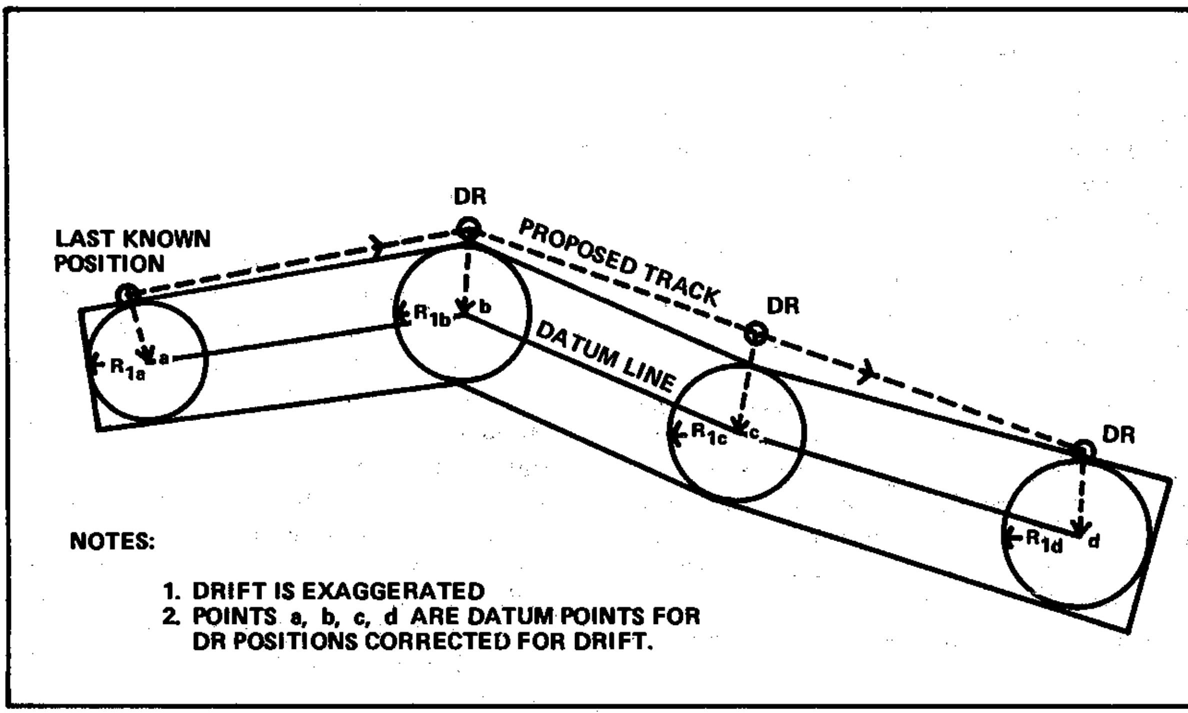


FIGURE 8-26

Search Area Expansion—Datum Line

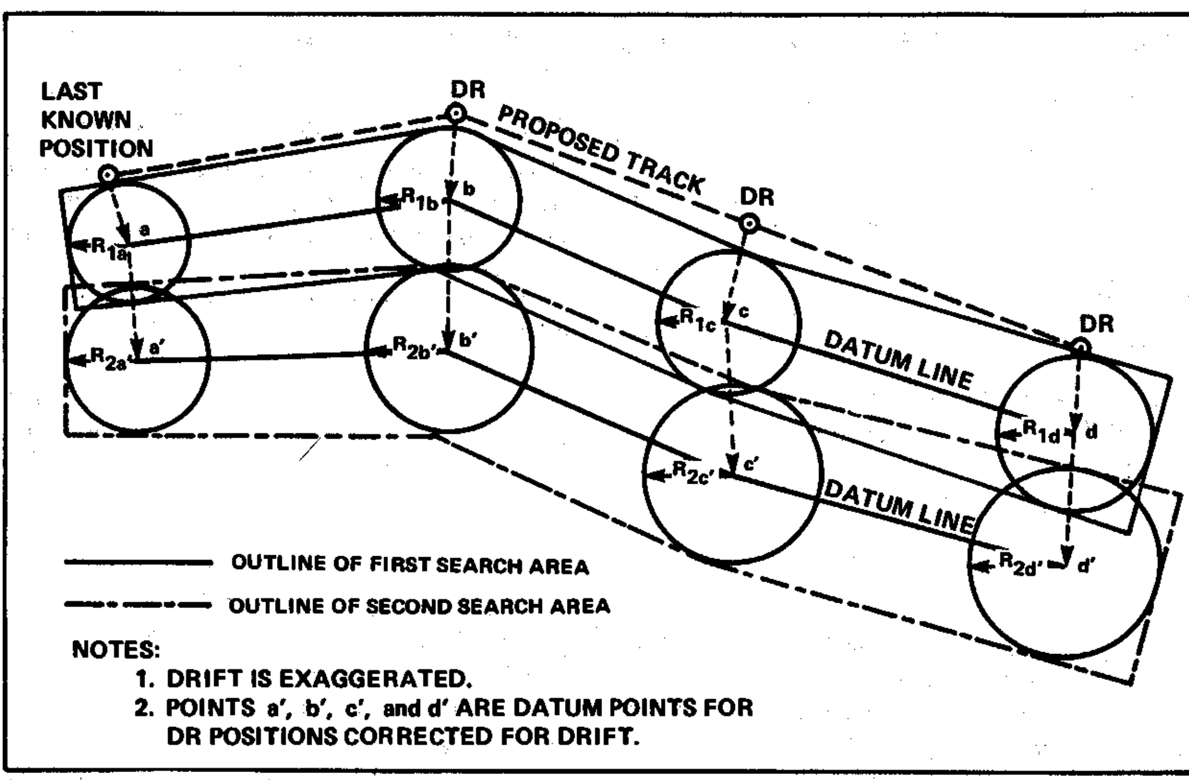
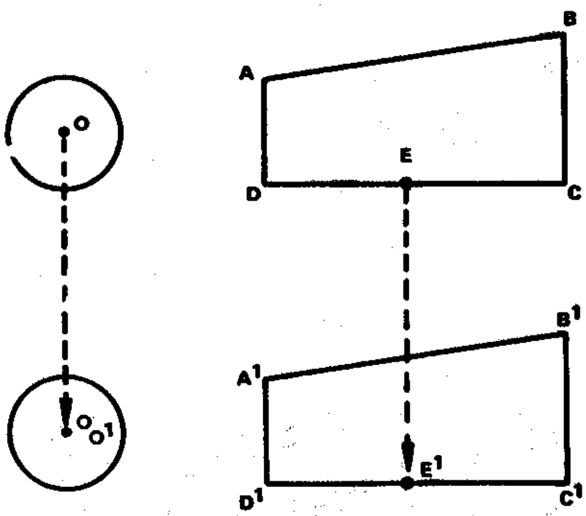


FIGURE 8-27

As in the case of point and line datums, drift must be considered with datum areas. In the case of small or medium sized areas, drift can be plotted using a single point, relocating the whole area for drift, keeping the original orientation, size and shape of the area relative to the point. See figure 8–28. If the area is so large that different drift factors act on portions of it, it will be necessary to calculate drift for representative sections. In such cases, the subsequent displaced areas will be warped out of their original shape.

Upon completion of each search, a reevaluation of the situation should be made to determine if the subsequent search should cover the same area, an expanded area or a different area entirely. In general, at least one re-search of areas selected is desirable unless evidence is developed which shows that available effort should be expended elsewhere.

Plotting Drift of Small and Medium Sized Datum Areas



DISTRESS IS KNOWN TO HAVE OCCURRED SOMEWHERE WITHIN CIRCLE O OR QUADRILATERAL ABCD.

DRIFT IS EXAGGERATED.

FIGURE 8–28

The following examples show how an original large Datum Area might be narrowed during the progress of a case:

(a) The initial search locates debris from the missing craft. The location of the debris is taken as a datum point and new search areas are developed based on this point.

(b) During the progress of the initial search, a relative of the operator of the missing craft is found who advises that the operator told him that he was going to a certain destination by as direct a route as possible. This information allows for plotting a datum line on which to base a new search plan.

(c) During the course of the search for a missing boat, a friend of the operator is located who advises that the only reason the operator ever went offshore before was to fish in a certain limited area and that he, the operator, had mentioned several days previously that he was planning another such trip. This narrows the original datum area down to where it can be treated as a small or medium sized datum area.

Occasionally a situation occurs where the original possibility area is so vast and clues so lacking that the action by the SMC is reduced to a search for information on which to base further action and/or an admittedly low probability search of the probable route of the overdue craft. In these cases, communications checks, including the alerting of transient craft, are most important as a means of obtaining information and of increasing the possibility of a chance sighting. Sightings of this nature occur more often than might be supposed.

826 Repeated Expansion Concept

The procedures explained above for successive enlargement of search areas is called repeated expansion. The concept has several advantages.

It is most suitable for situations in which the distressed craft's approximate position is known (datum point).

The standard concept of repeated expansion calls for five successive searches with the center of the area of search based on the datum point. This does not imply that effort should be spared, or that the search be needlessly dragged out. Often, however, even a maximum effort search may fail to locate a target during the initial search of an area. The search planner must be prepared to repeat and expand the search in such cases, and repeated expansion provides a framework for such action.

It also provides a planned build-up for less urgent missions. Each search covers a larger area than the one before. At the end of five searches, an area equal in size to the first search area has been searched five times while the area at the outer edge of the fifth search has only been searched once. This results in a high probability of detection at the center, decreasing to the outer edge.

As the target is most likely to be near the datum and least likely to be at the outer edges of the fifth search area, the heaviest search effort and greatest probability of detection is concentrated at the most likely position of the target.

At the same time, the search area has been expanded to a radius 2.5 times the total probable error.

827 Use of Case Information To Improve Search Area Planning

a. General

It is essential that all information be carefully examined. Some of it may give definite indications that the operator of the distressed craft took a different course from the one that might otherwise have been expected of him, or other information may show that special circumstances influenced the location of the distress scene. For instance, unreliable or unserviceable navigation aids in the area or navigation equipment on board may have caused the pilot to deviate from his intended track; sighting reports may indicate that the pilot did deviate from his track; weather conditions or the nature of the terrain may have induced him to look for a more suitable landing area; his habits and training may give some indication what he might have done in an emergency; radio signals and weather reports from survivors may help to determine their approximate whereabouts, etc. Circumstances such as these may make it possible to reduce the boundaries of a search area, or may make it necessary to increase them or even to move the area elsewhere.

b. Aircraft Missing

Aircraft accidents which are attributable to adverse weather conditions often require a more intensive and prolonged search because of the uncertainties that surround many such accidents. Atmospherics may have made radio reception poor and been a primary cause of an aircraft becoming lost; lightning strikes may have caused complete failure of radio equipment; severe turbulence or icing may have caused an aircraft to lose altitude or divert off track; or clouds or fog may have reduced visibility so as to make it impossible for the pilot to determine his position prior to making a forced landing, etc. However, a complete analysis of the weather conditions that prevailed in the area where the aircraft was flying at the time of its disappearance may help to determine the probable actions of its pilot and narrow down the area in which it may have crashed.

c. Survivor's Radio Signals

If survivors can transmit any type of radio signal, their chances for early location and rescue are increased enormously.

The most obvious advantage of survivors' radio signals is that search aircraft will be able to either home in directly to the survivor's position, or use one of the homing search patterns to locate the survivor's position.

Even if no search unit is available within radio range, a radio DF net may be able to obtain a fix or at least a line of position.

Enroute aircraft which have the appropriate frequencies should always be requested to listen for radio signals from survivors even if the aircraft cannot divert from their track. Just the fact that a survivor's signal was heard at a certain location can be used with radio horizon computations to develop a line of position.

If for any reason, DF bearings or homing cannot be used, it may be possible to deduce an approximate position of the survivors by using one of the following procedures, assuming that two way communications exist.

1. Survivor Line of Position From Sun. In this procedure the time of sunset, as observed by survivors, is used to determine the longitude of their location in the following manner:

(a) The survivors are requested to send a signal at sunset, exactly when the upper limb of the sun is seen to be on the horizon. This is usually accomplished by sending a succession of dots as the sun sinks on the horizon and a long dash as its upper limb disappears. This is illustrated in figure 8–29.

(b) The time of the sunset, as indicated by survivors, is carefully noted by the receiving station which then informs the RCC.

Survivor LOP From Sun

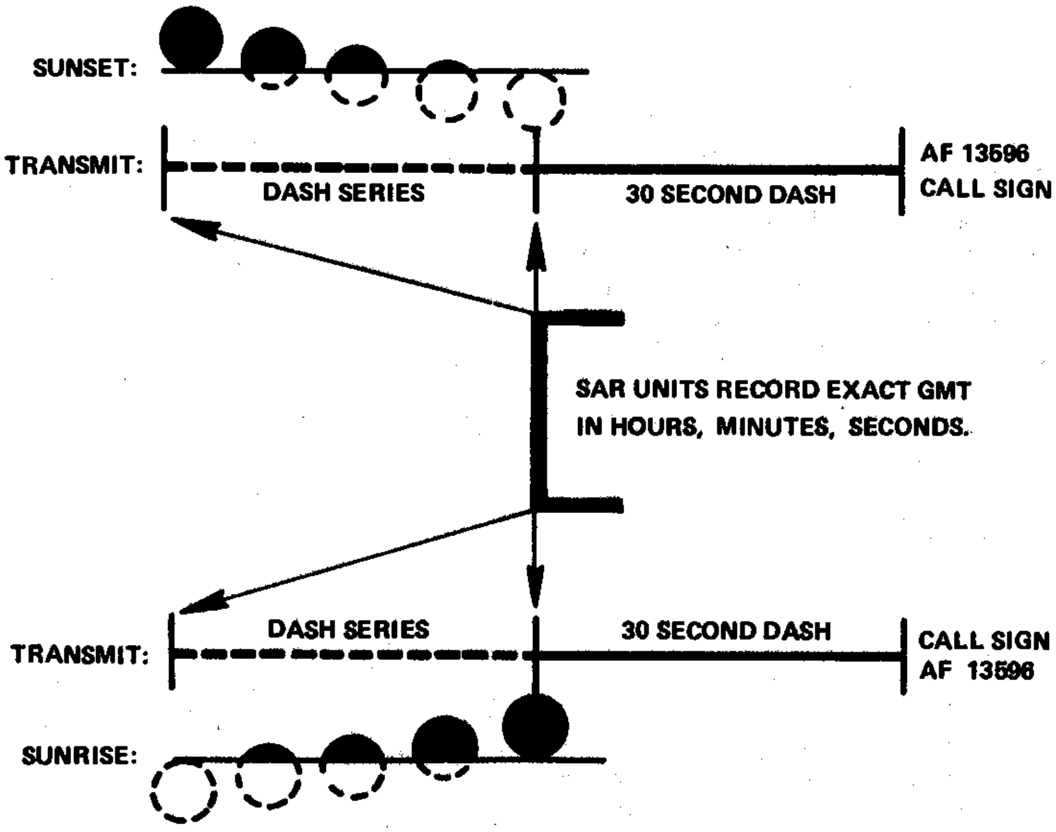


FIGURE 8-29

(c) From bearings taken and other information received an assumption is made of the survivors' latitude.

(d) Assuming this latitude, the air almanac or nautical almanac is entered at the appropriate date and the time of sunset for the assumed latitude at the Greenwich Meridian is extracted. A comparison with the time of sunset (GMT) at the position of the survivors is then made. Their longitude may now be established by virtue of the fact that each 4 minutes' difference in time represents 1 degree of longitude; observed sunset ahead of tabled sunset = east longitude, observed sunset behind tabled sunset = west longitude.

Unless unusual refraction conditions prevail (the tables make a correction for normal refraction) and unless the assumed latitude is very inaccurate, a reasonably correct longitude will be determined. This method is suitable for survivors adrift at sea or in flat land areas (coast, desert, etc.).

A similar procedure may be used for sunrise, and moonset or moonrise. Star settings are generally unsatisfactory as stars usually disappear in haze before reaching the horizon. In any event their refraction index is likely to be considerable and very variable.

Some survival manuals suggest this method for sunrise and sunset when emergency radio transmitters are in the possession of survivors. The transmission will be made in the blind. Radio stations, hearing the distinctive signal should be alert to record the time of the start of the long dash.

2. Survivor LOP/Fix With Sextant. For this procedure it must be assumed that the survivors have a sextant and a watch with a second hand (its time setting is immaterial). The survivors are requested to carry out the following actions:

(a) Take a sight of the sun at, say, 1000 local time. Note its altitude and the time of the observation very carefully with the second hand on the watch.

(b) At any time thereafter transmit a message to the effect that at the commencement of the long dash it is exactly x minutes (say 5) since the sun was observed at altitude $y°$ and z'.

(c) Repeat the procedure at, say, 1400 local time.

Receiving stations can now determine the sun's altitude at the survivors' position with considerable accuracy in terms of GMT and obtain a fix from this information. Similar procedures may be adopted in respect of any celestial body. At night, by choosing two suitable stars, a fix may be obtained immediately after the observations have been communicated.

d. Survivor Weather Reports

In this procedure survivors are requested to transmit weather reports, if possible, on a scheduled basis. From these reports it may be possible to ascertain the position of the survivors.

828 Describing Search Areas

After the search area is computed it will be necessary to describe it to the search units assigned. Large search areas must be divided into smaller subareas of a size that individual SRUs can complete in their allotted or available on scene endurance time. There are several possible methods for describing search areas.

a. Naming of Areas

When referring to specific search areas some method of naming them is desirable. Whatever system is chosen, it should be flexible enough to be used over several days of operations with many individual search areas. The following system has proven very workable for either small scale or large search operations.

The overall search areas are named alphabetically beginning with *A*, in accordance with the sequence of coverage. For example, the search areas used in the first search effort are Alfa areas; the search areas used in the second search effort are the Bravo areas; the third search effort areas are Charlie areas; and so on. Subareas assigned to individual search units are given a numerical identity. Thus any number of search units can be assigned to specifically named subareas without the naming system becoming unwieldly.

For example, suppose the SMC computes the search area for his first search and divides it into three subareas for specific assignment to three different search craft. The search areas are named A–1, A–2, A–3. The first search effort is unsuccessful so the SMC, using the second search safety factor, expands the original search area. He divides the enlarged area into four subareas. These are named B–1, B–2, B–3, B–4.

b. Boundary Method

Any square or rectangular area that is oriented east-west or north-south can be described by stating the two latitudes and two longitudes. Any inland search area that is bounded by prominent geographical features can be described by stating the boundaries in sequence. For example,

1. D–7 Boundaries 26N to 27N Between 64W to 65W.

2. A–1 Boundaries highway 15 to the south, Lake Merhaven to the west, Runslip river to the north and Bravado mountain range to the east.

The Boundary Method is one of the preferred methods.

c. Corner Method

Any area except circular areas can be described by stating the latitude and longitude or geographical feature of each corner in sequence. For example:

1. E–7 corners 2315N 7435W to 2310N 7325W to 2220N 7325W to 2225N 7425W to origin.

2. A–6 corners Stony Tavern to Red River bridge to Gunder Cave to origin.

The Corner Method is one of the preferred methods.

d. Center Point Method

Any circular, square or rectangular search area can be described by stating the latitude and longitude of the center point, plus the length of the search radius if a circular area, or the direction of orientation of the major (longer) axis, and the lengths of the major and minor axis, if a square or rectangular area. For example:

1. A–3 center point 34°–17′ N 116°–22′ W, 025° T, 80 by 40.

2. B–2 center point 33 N 60 W, radius 10.

The center point method is very convenient as it can describe all but irregular search areas, and is very short to transmit.

The Boundary Method or Corner Method are preferred over the Center Point Method because the latter requires more plotting, makes detection of plotting errors more difficult and, if plotted on a chart of different projection from that used by the SMC (e.g. Lambert Conformal vs Mercator), will result in plots of adjoining areas which do not have the same boundaries or corner points.

e. Track Line Method

Track line search areas may be described by stating the track and the width of coverage. For example:

1. C-2 trackline 2406N 7855W to 2450N 7546W. Width 50 NM.

f. Grid Method

Many areas are divided into grids on local grid maps. Use of these grids permits accurate positioning and small area referencing without transmitting lengthy geographical coordinates. However the SMC must insure that all search units have possession of the same grid charts. Instances have occurred which endangered search units when search areas overlapped due to different grid systems being used.

g. Georef Method

This system may be used for describing square or rectangular areas oriented N–S or E–W, on maps overprinted with a Georef grid.

Example: Search area only: CGVM; search area plus probable location: CGVM 3050. The SMC must insure all search units have possession of Georef grids to avoid hazarding search units.

830 SEARCH PATTERNS

Once the location and size of a search area have been determined, a systematic search for the target must be planned.

Search pattern selection depends on several factors such as accuracy of datum, size of the search area, SRUs available for search, maneuverability and navigational accuracy of the SRUs, horizontal and vertical separation of search aircraft, weather and sea conditions in the search area, size of search target, type of detection aid survivors may have, etc. They are obviously interrelated but in any particular situation some factors may prove more important than others. In planning a search and rescue operation the SMC should endeavor to meet the requirements of the more important factors while satisfying the others as nearly as possible.

The type and number of available SRUs will be a controlling factor in the selection of the search pattern. For instance, an aviation unit which does not have enough aircraft for carrying out a prolonged search of a large area will require more time for searching it thoroughly, unless the track spacing of the search pattern is increased. This, however, is not desirable since it will also reduce the probability of detection. Rather, additional aircraft should be sought from other sources. It is nearly always preferable to cover a search area from the onset with a large number of aircraft, rather than cover it with a few aircraft section by section.

Range, type, and speed of the aircraft employed are equally important. When the aircraft have to operate far from their home base, they should be deployed to an advance base so that more time will be available for the searches and less time will be spent on flights to and from the search area. An aircraft with an adequate number of well-placed observer stations will give observers a better chance to detect a target. A slow aircraft will increase that chance further as scanning procedures can be carried out more thoroughly.

When appropriate, patterns should initially be selected with the idea of locating survivors as rapidly as possible by using the maximum track spacing for radio, visual, or other signaling aids that the survivors possess, keeping in mind that the survivors will be in better physical condition to use these aids during the initial periods of the search, and that battery transmission life of locater beacons is limited to between 24 and 48 hours as a general rule.

831 Navigational Accuracy of SRU's

The navigational accuracy of available SRUs is a primary consideration for selecting the types of patterns to be used, particularly if the available search units are aircraft. While the accuracy of navigation of surface craft is generally not too great a problem, aircraft present a more difficult picture due to drift from prevailing winds. The probability of detection curves are valid only when the search pattern tracks are accurately followed.

Significant errors will result from accumulated errors in turns and from wind forecast errors, especially for high speed aircraft. Consideration must be given to selecting the type of pattern which gives minimum turns and maximum search leg lengths in order to reduce turning errors and to make it easier for navigation observations and corrective action. However, there may be a limit to the maximum search leg lengths when the search area covers water surfaces with strong currents or with high survivor drift rates. In these circumstances aircraft search legs are usually limited to 30 minutes or less of flying time if the legs are oriented across the drift direction. This is to avoid the possibility of the survivors drifting from one side of a track to beyond the next search track by the time the search aircraft returns to that same general area. A more satisfactory solution to this problem is to orient the search legs with the drift direction.

Greater search accuracy is obtained when visual, radar, or radio navigational aids are within reception range of search units or when aircraft are equipped with inertial navigational systems. If an area is in a good LORAN, OMEGA, TACAN, or VOR receiving area, accurate and continuous-fix information is available for maintaining the search unit on its search legs. If the search area is in an area where navigation aids are few or nonexistent, it must be realized that search navigation will be by dead reckoning (DR) navigation. Forecast winds will have to be modified by visual observation of the surface. The navigator must take frequent drift readings and check compass headings on each search leg in order to maintain proper tracks. Celestial navigation, even when possible, is not feasible for keeping the aircraft accurately positioned on short, closely spaced search legs.

Because of this air navigation problem, the coordinated aircraft/marine craft type of search is used whenever possible. The surface vessel, acting either as a fixed or moving reference point in the search area, permits aircraft to fly tracks within very close limits of accuracy. Surface vessels, when radar equipped, can furnish advisories to keep the aircraft on the desired track. The vessel also can relieve the aircraft of most of its communications load as well as provide ready assistance to the aircraft if trouble develops.

When dividing up the total search area into areas for assignment to individual SRUs it should be kept in mind that elongated search areas are covered better navigationally than small square areas. When two or more search aircraft are available, elongated search areas are preferred.

832 Search Pattern Types

a. General

It is always good practice for the SMC to specify the Commence Search Point (CSP) when dispatching search units to a search area. This permits the SRU to plan his en route track with best efficiency, and it insures that the SRU will at least begin its search pattern at the proper point. This is particularly important when several SRUs are arriving in an area at about the same time. It will help insure that adequate safety separation is kept between SRUs. It also permits the SMC to control the direction of creep for search efficiency. The pattern figures in this section indicate the desired CSP for single-unit patterns and for the "guide" unit in multiunit patterns.

Except for sector search patterns track spacing (S) is the distance between adjacent search legs of the search pattern. S is indicated on all patterns. Search legs are not located on the exact boundary edge of search areas. Rather, they are located a distance equal to one-half of the track spacing inside the area boundary. This insures reasonable safety for SRUs in adjacent areas.

b. Main Pattern Groups

There are eight main groups of search patterns. They are:

1. T—Trackline.
2. P—Parallel.
3. C—Creeping line.
4. S—Square.
5. V—Sector.
6. O—Contour.
7. F—Flare.
8. H—Homing.

These groups are further broken down into specialized patterns, generally by how many SRUs are used, by how the pattern is coordinated or oriented, or by the position of the entry and departure points of the search area. While such a detailed division of search patterns is not always used, it is useful for SAR purposes in order to prevent misunderstanding and to afford each user a pictorial presentation of the pattern to be used. Search and rescue missions may involve many units and persons having little or no experience in this specialized type of operations, and the simplest presentation of the patterns is desirable.

c. Pattern Labeling

The general system used in labeling search patterns is:

1. First letter—General pattern group T, C, P, V, S, O, F, or H.
2. Second letter—Number of search units:
   S—Single search craft or search person.
   M—Multiple search craft. If both marine craft and aircraft are required, only the primary searching craft are counted.
3. Third letter—Supplementary pattern information:
   C—Coordinated or circle.
   R—Radar coordinated or return to starting point.
   N—Non-return to starting point.
   A—Arc of circle, or aural.
   L—Loran line.
   S—Spiral.

d. Trackline Patterns (T)

There are four forms of trackline patterns: TSR, TMR, TSN, and TMN. These patterns are used when a craft or person is missing and the intended route of the missing craft or person is the only search lead. A route search is usually the first physical search action taken. It is always assumed that the distressed craft or lost person is on or near its track or route, and that it will either be easily discernable, or there will be survivors capable of signaling when they hear or see search units. The trackline pattern is a rapid and reasonably thorough coverage of the missing craft's proposed track and the area immediately adjacent to it.

1. Trackline Single-Unit Return (TSR). The Commence Search Point (CSP) is offset ½ search track spacing from the trackline.

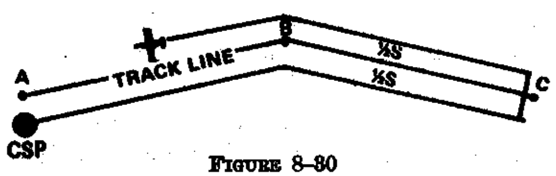


FIGURE 8-30

2. Trackline Multiunit Return (TMR). Two or more search units used in an abeam formation to afford greater width coverage along track.

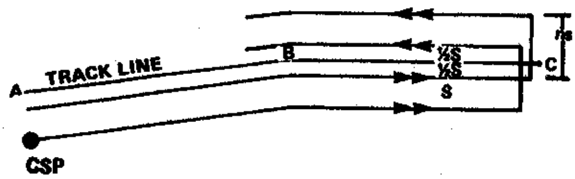


FIGURE 8-31

3. Trackline Single-Unit Nonreturn (TSN). Same as TSR except search terminates at opposite end of track from which it was begun.

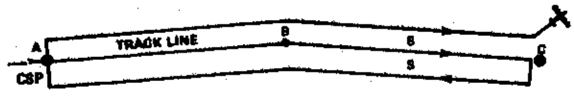


FIGURE 8-32

4. Trackline Multiunit Nonreturn (TMN). Same as TMR except search terminates at opposite end of track from which it was begun.

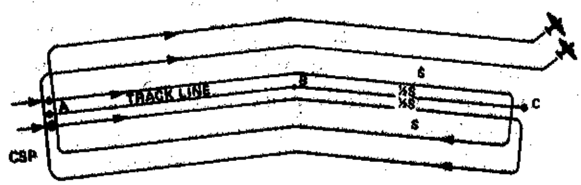


FIGURE 8-33

e. Parallel Patterns (P)

There are nine forms of parallel search patterns: PS, PM, PMR, PMN, PSL, PSA, PSC, PMC, and PSS. There are two general subgroups of parallel patterns: Those with straight search legs and those with curved search legs. Parallel track patterns have straight search legs, while parallel circle and parallel arc patterns have curved search legs. Parallel track patterns are normally used when:

(1) The search area is large and fairly level;

(2) Only the approximate location of the target is known; and

(3) A uniform coverage is desired.

Parallel track patterns are best adapted to rectangular or square areas. Search legs are aligned parallel to the major axis of rectangular search areas.

Parallel circle patterns are normally used for small search areas underwater by swimmers although not exclusively for this purpose.

Parallel arc patterns are normally used in areas where DME, TACAN, or other distance measuring navigational aid is available to the search unit. The size of the search area is not a factor when selecting a parallel arc pattern; the navigational net coverage is the controlling factor.

1. Parallel Track Single-Unit (PS).

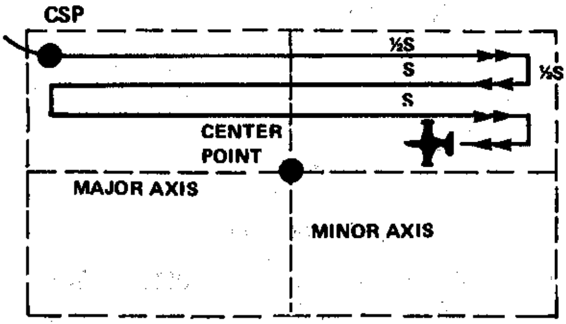


FIGURE 8–34

2. Parallel Track Multiunit (PM). This pattern provides very accurate track spacing, fast area coverage, and an increased safety factor for aircraft over water.

One search unit is designated as guide and handles navigation, communications, and control of team. Turns at the end of search legs should be carried out by signal from the guide. Cross legs are a distance equal to the track spacing multiplied by the number of search units in the team (nS). Land search units use the procedure described in chapter 9.

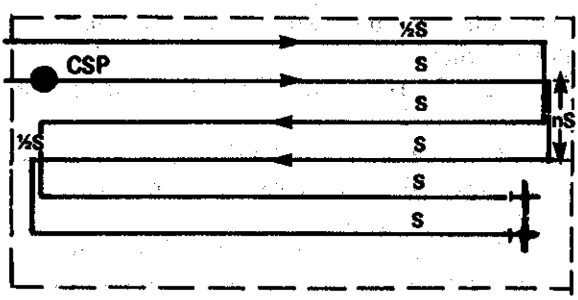


FIGURE 8–35

3. Parallel Track Multiunit Return (PMR). This pattern is used when simultaneous sweep of an area to maximum radius is desired. It provides concentrated coverage of large areas in a minimum period of time and allows the use of aircraft with different speeds in a parallel search pattern.

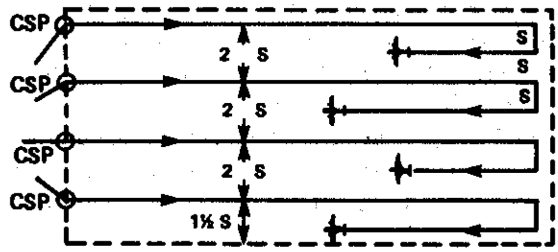


FIGURE 8–36

4. Parallel Track Multiunit Nonreturn (PMN). This pattern is similar to the PMR, except search units continue on to a destination other than the departure point. It is normally used when enroute vessels or aircraft are available and will alter their tracks a small amount to provide uniform coverage of the search area, when passing in the same general vicinity.

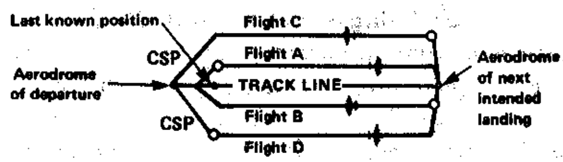


FIGURE 8–37

5. Parallel Track Single-Unit Loran Line (PSL). This pattern is one of the most accurate search patterns for aircraft searching alone in areas covered by Loran, Decca, Omega or similar navigation nets. The pattern must be orientated so that the search legs flown by the search unit are parallel to a system of Loran lines, Omega lines, etc.

Loran lines are selected at the track spacing desired. As each leg is flown, the selected Loran line reading is pre-set on the Loran receiver-indicator. The Loran operator has then merely to coach the pilot to keep him on the pre-set Loran line, and thereby on track.

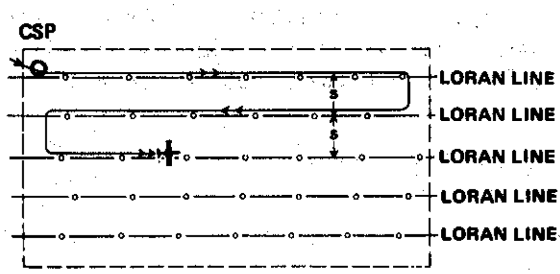


FIGURE 8–38

6. Parallel Single-Unit Arc (PSA). This pattern is used by search craft for areas which have DME, TACAN, VORTAC, or similar distance measuring navigation net coverage. It gives the benefit of accurate track guidance. However, this pattern will be more difficult to execute than the one based on LORAN position lines. Figure 8–39.

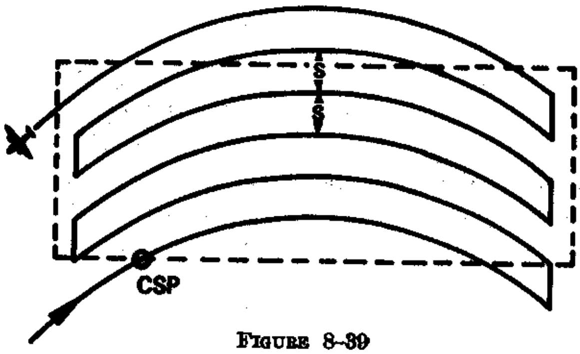
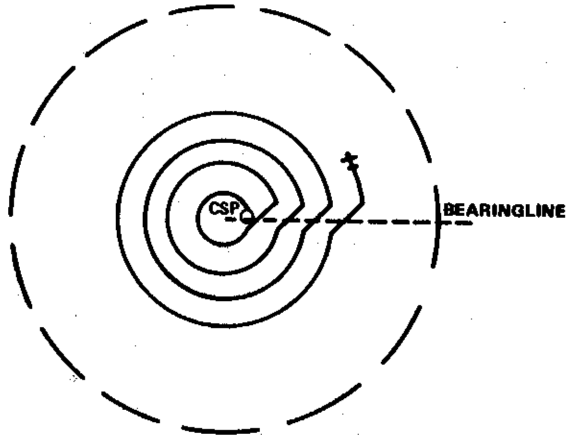


FIGURE 8–39

7. Parallel Single-Unit Circle (PSC). This pattern is similar in execution to the PSA except one complete circle is made before shifting to the next search leg. If all leg shifts are made on the same bearing line from the navigation station, uniform coverage is obtained with very good accuracy. This pattern is used only when a distance measuring navigation net, such as TACAN, blankets the search area. This pattern is also used when the search craft can drop an SAR datum marker beacon of either the TACAN or RADAR types from which it can obtain both distance and bearing information. Figure 8–40.

8. Parallel Multiunit Circle (PMC). This pattern is used by two or more swimmers for underwater search of very small areas, generally less than 25 yards in diameter. A line or rope is knotted along its length at distances equal to the desired search track spacing. The line is then anchored in the center of the area and swimmers use the knots to maintain uniform coverage. Swimmers begin with the innermost knots, search one set of circles, then shift outward to the next set of knots. Figure 8–41.



PSC Pattern

FIGURE 8–40

9. Parallel Single-Unit Spiral (PSS). This pattern is used by a single underwater swimmer for search of very small areas, generally less than 25 yards in diameter. The swimmer uses a line or rope coiled on a fixed drum in the center of the area. He then swims and searches in ever increasing spirals, using the line to maintain proper search track spacing by keeping it taut at all times as it uncoils with his movement. Figure 8–42.

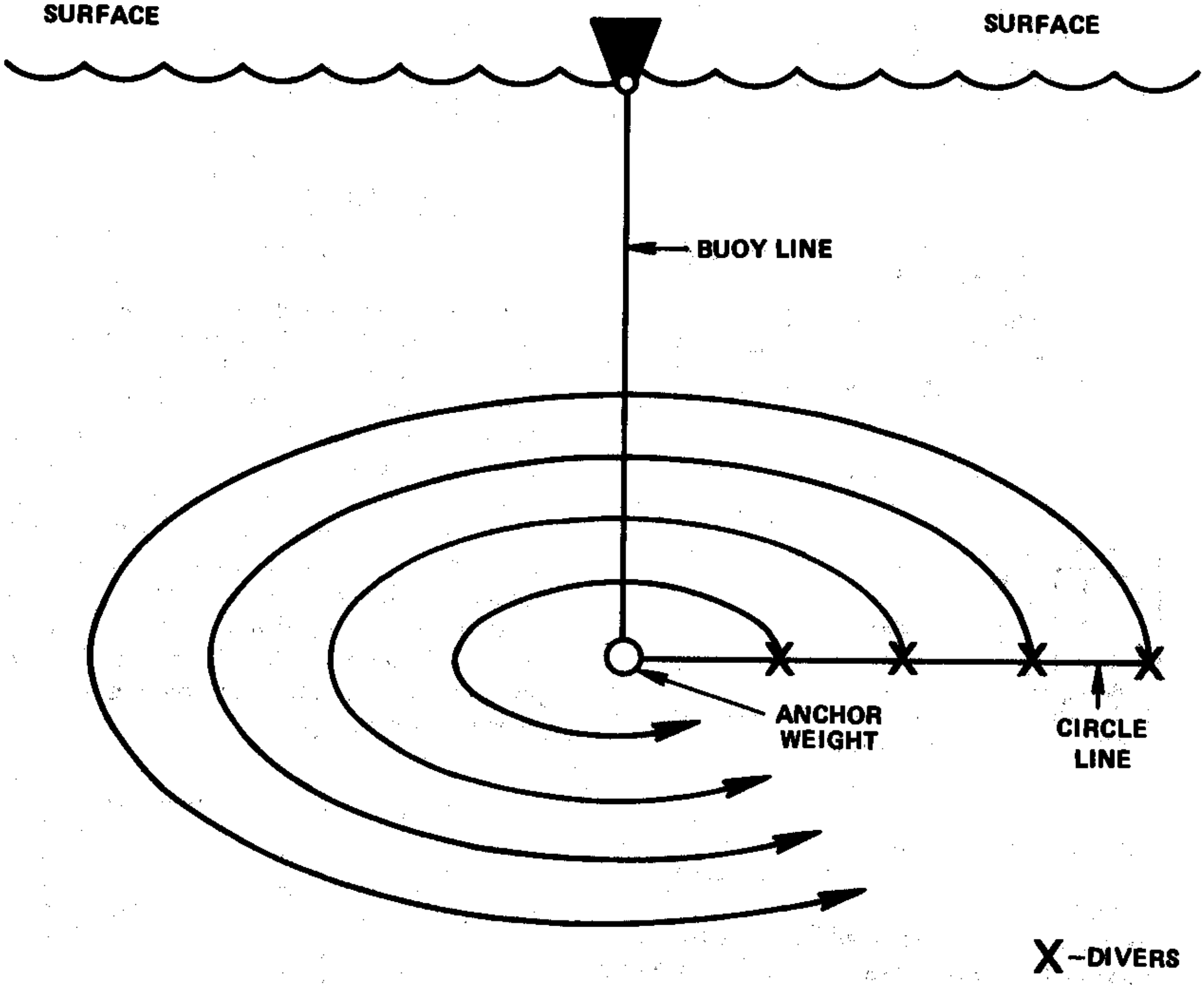
f. Creeping Line Patterns (C)

There are seven forms of creeping line patterns: CS, CM, CSC, CMC, CSR, CMR, and CMS. These patterns differ from the parallel track pattern only in that the search legs are parallel to the minor axis (shorter axis) of a rectangular or elongated search area. They are selected when:

(1) the search area is narrow, long and fairly level;

(2) The probable location of the target is thought to be on either side of a line between two points; and

(3) Immediate coverage of one end of the area, followed by rapid advancement of successive search legs along the line, is desired.



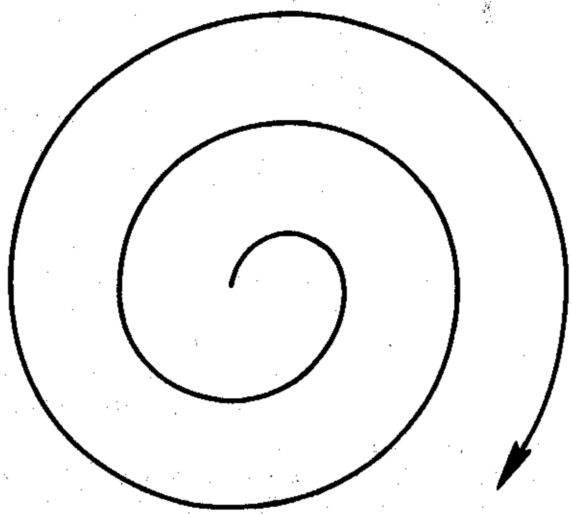
PMO Pattern

FIGURE 8–41

1. Creeping Line Single-Unit (CS). The commence search point (CSP) is located ½ search track spacing inside the corner of the search area. Figure 8–43.

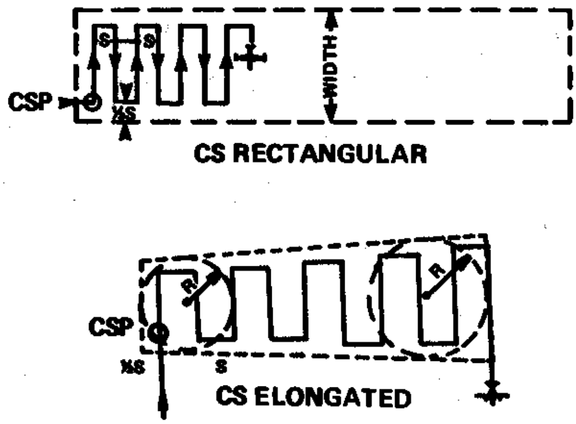
2. Creeping Line Multiunit (CM). This pattern is the same as CS except two or more search craft are used cruising abreast with turns and cruising control in the same manner as with the PM search pattern. Figure 8–44.

3. Creeping Line Single-Unit Coordinated (CSC). Coordinated creeping line patterns should be employed when aircraft and either vessels or boats are available. The track of the aircraft is planned so that the advance of the successive legs of the search pattern equals that of the marine craft, and the aircraft passes over the vessel on each leg. This results in a more accu-



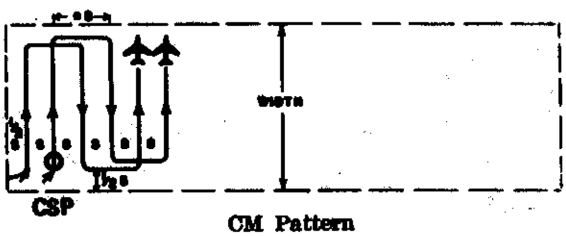
PSS Pattern

FIGURE 8–42



CS Pattern

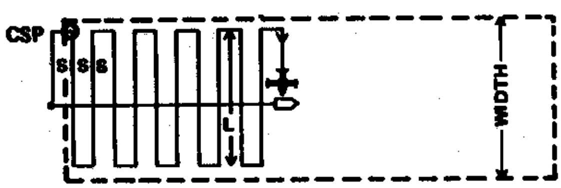
FIGURE 8-43



CM Pattern

FIGURE 8-44

rate search pattern, and rescue by marine craft can be effected within a short time once survivors have been located by the searching aircraft. Coordinated patterns should be started before entering the search area so that full coverage of the area will be assured. See chapter 9 for procedures for coordinated patterns. Figure 8-45.



CSC Pattern

FIGURE 8-45

4. Creeping Line Multiunit Coordinated (CMC). This type pattern provides a more accurate search with faster coverage. This pattern is the same as CSC except two or more search aircraft are used cruising abreast, with crosslegs being flown equal to track spacing multiplied by the number of search aircraft (as in CM). In this type search, the guide aircraft passes over the ship on each leg, other aircraft maintaining station on the guide at distance S apart.

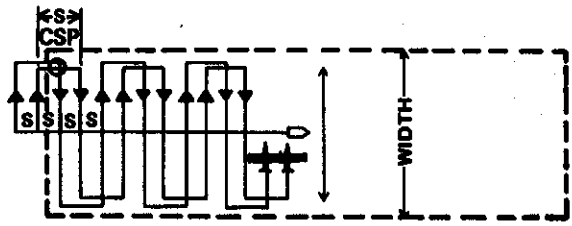


FIGURE 8-46

5. Creeping Line Single-Unit Radar (CSR). This pattern is the same as (CSC) except that the ship assists the aircraft in keeping on course by frequent radar advisories. The ship also advises the pilot when he is five miles from the end of each leg and at the time to turn onto crossleg to facilitate accurate coverage of the crossleg areas. Advisories of distance off course should be given on the basis of an average of several fixes. Whenever the aircraft is within the visual range of the ship, visual bearings should be taken and plotted with radar ranges. This will prove more accurate than relying on radar bearings exclusively.

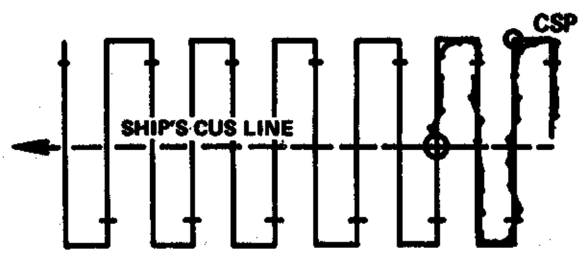


FIGURE 8-47

6. Creeping Line Multiunit Radar (CMR). This pattern is the same as (CSR) except two or more aircraft are used in an abeam formation at distance S apart. The surface unit tracks and plots only the guide aircraft. Aircraft turn together on the crosslegs and move over a distance equal to track spacing multiplied by the number of aircraft (nS). If difficulty is experienced with bearing discrimination or shipborne air search radar, the guide aircraft should take station a half mile ahead of the other aircraft to improve radar identification.

7. Creeping Line Multiunit Coordinated Split (CMCS). Like its name, this pattern is difficult to compute and cumbersome to execute. However, when a large aircraft speed differential prevents using the CMC, or if the search craft desire, it may be used. Some pilots prefer this pattern as they do not have to fly formation on a leader.

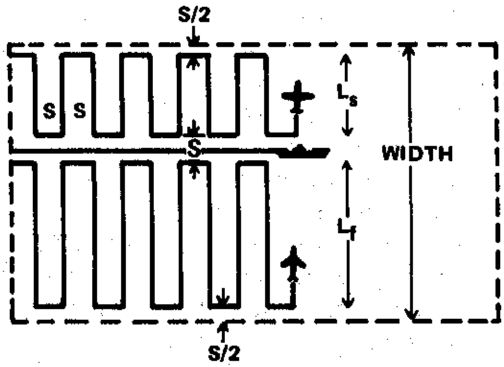


FIGURE 8-48

g. Square Patterns (S)

There are two forms of square search patterns: SS and SM. These patterns are used for concentrated search of small areas where the position of survivors is known within close limits and the area to be searched is not extensive. If error in position is expected, or if the target was moving (aircraft about to ditch, bailout, etc. or a crippled ship that has heaved to or is proceeding at a very slow speed), the square pattern may be modified to an expanding rectangle with the long legs running in the direction of the target's reported or probable movement.

1. Square Single-Unit (SS). The first leg is usually directly into the wind or current in order to minimize navigation-errors. Square searches are often referred to as expanding square searches as they begin at the initially reported position or Datum Point and expand outward in concentric squares. It is a very precise pattern requiring the full attention of the navigator. Figure 8–49.

2. Square Multiunit (SM). The many turns of this pattern will make it impossible for two search craft to conduct an expanding square search in an abeam formation. When marine craft are used they should each start an independent expanding square pattern with staggered starting time, and the axis of search for each unit should differ by 45° from the one ahead. When two aircraft, the maximum, are assigned to an SM pattern, they must fly their individual patterns at different altitudes on tracks which differ by 45° from each other. Figure 8–50.

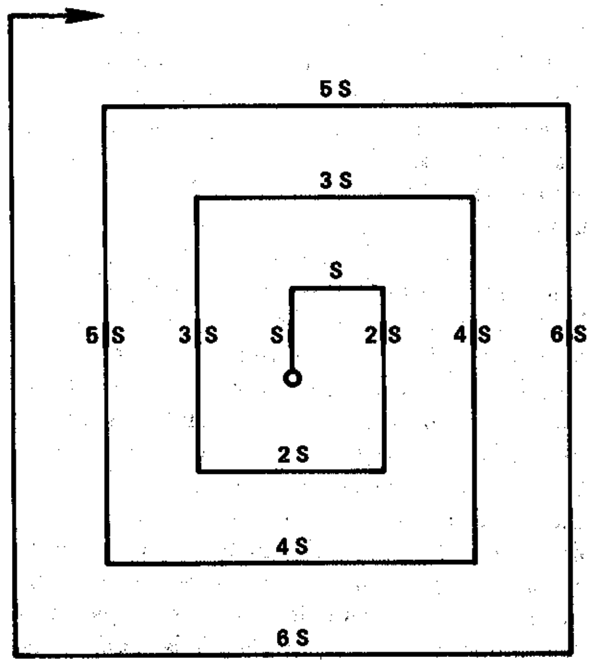


FIGURE 8-49

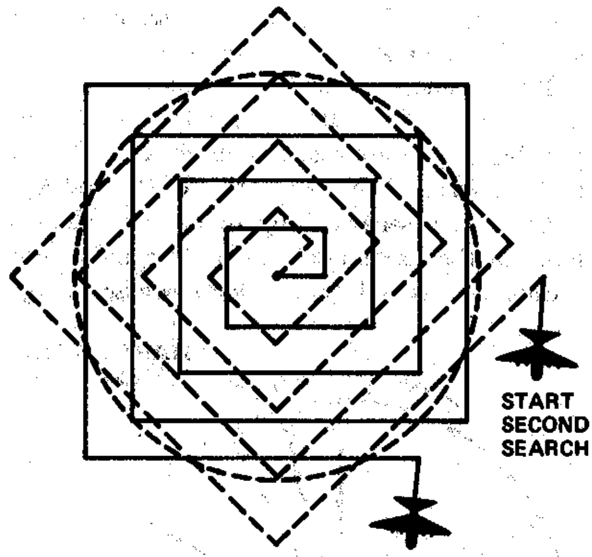


FIGURE 8-50

h. Sector Patterns (V)

There are four forms of sector search patterns: VS, VM, VSR, and VMR. These patterns are used when the position of distress is known within close limits and the area to be searched is not extensive. The pattern resembles the spokes of a wheel and covers a circular search area. A suitable datum marker in the center of the search area can be used as a navigation aid on each leg. The marker may be a smoke float, radio beacon, tacan beacon, radar beacon, life jacket, buoy, box, or similar piece of equipment. This pattern is extremely easy to execute for either aircraft or marine craft. Generally aircraft sector search areas do not have a radius greater than 20 to 30 miles, while marine craft use a maximum radius of 5 miles.

Compared with the square search, this pattern is not only easier to execute and navigate, but it is also more effective. The track spacing is very small towards the center and this ensures an increasingly intensive coverage in the area where the target is most likely to be found. If a further search is necessary, it should be carried out on tracks plotted half-way between the tracks of the pattern flown during the first search. The first search leg is usually oriented North to keep angle computations simple. When computing probabilities of detection for sector patterns, maximum track spacing (S_{max}) is used to develop the minimum probability. Maximum probability is always 99 percent. For example, probability of detection after a sector search might be described as 63 to 99 percent.

The commence search point may be at the perimeter of the pattern or at the datum, depending on the approach being made to datum by the SRU and the orientation of the first leg.

Each leg is separated by an angle θ (Theta), based on the maximum track spacing and search radius. At the end of each leg a course change angle β (Beta) will turn the search craft onto the cross leg, which is the maximum track spacing. θ, β and other data is tabulated on the nomograph in figure 8–77. Only the number of sectors (N) listed in figure 8–77 should be used. Any other number of sectors will not give equal coverage within sectors. For standardization, all turns should be made to the right unless there is a compelling reason to do otherwise.

1. Sector Single-Unit (VS). The four-sector and six-sector searches are most commonly used for single search craft using the sector patterns. The four-sector pattern will have 90° between each successive radius, and only two search legs (diameters) and one cross leg equal to 1.4 times the search radius, are required to complete the pattern. To obtain smaller track spacing, simply rotate the pattern orientation 45° after completion of the first pattern. Completion of the next two search legs will give a total coverage of the area as though 45° had been used from the beginning. This sequence can be repeated by placing the next two coverages midway between the 45° search legs.

The six-sector pattern is probably the easiest to use since it is made up of three equilateral triangles with one corner of each triangle in the center of the search area (at datum). Refer to figure 8–52. Notice that the search radius (R) is also the length of the crossleg. And notice that the maximum track spacing, S_{max}, is also equal to the search radius. θ is 60° while β is 120°. To obtain smaller track spacing, simply rotate the

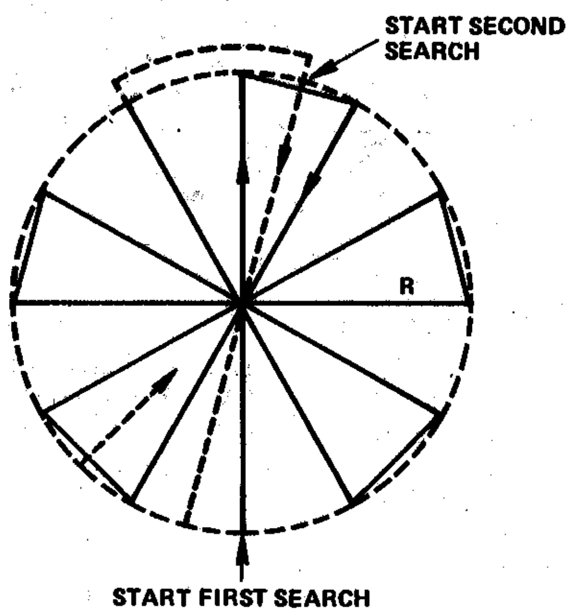


FIGURE 8–51

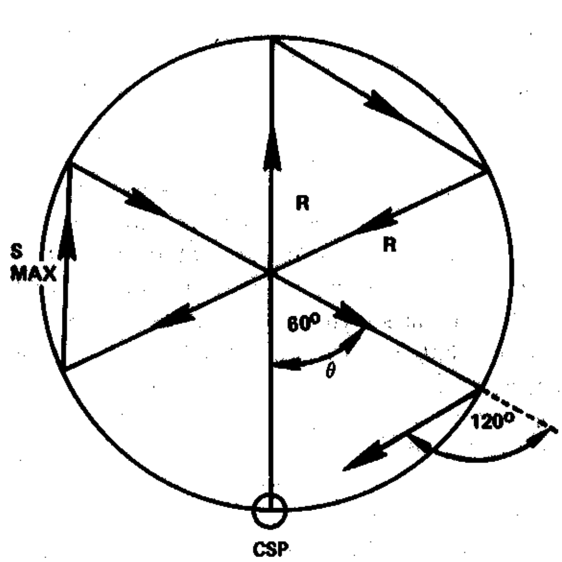


FIGURE 8–52

pattern orientation 30° after completion of the first pattern.

Sector patterns with different central angles may be chosen from figure 8–77.

2. Sector Multiunit (VM). Up to three aircraft can be assigned to a multiunit sector pattern. With more than that, the pattern becomes unwieldy. When aircraft are used in a VM pattern they must fly at different altitudes. Each aircraft is assigned two sectors diametrically opposite and of equal size. Figure 8–53 depicts these individual assignments. A special type of VM pattern for boats is provided in the U.S. Coast Guard Addendum to this manual.

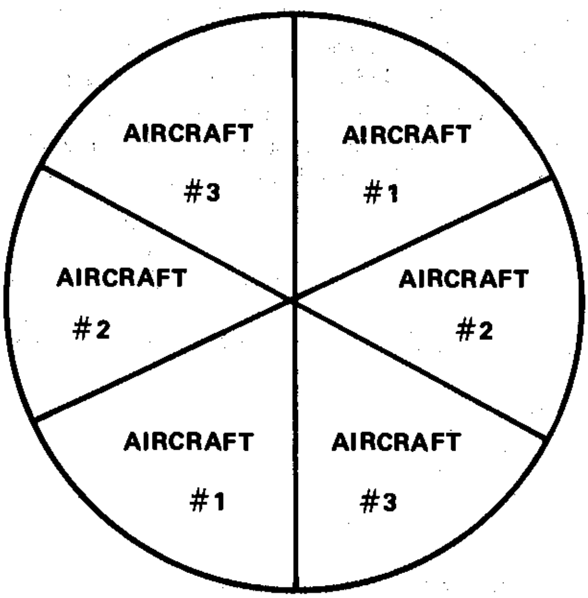


FIGURE 8–53

3. Sector Single-Unit Radar (VSR). This pattern is used when a radar-equipped marine craft takes station at the center of the pattern and provides radar navigation assistance to one search aircraft in completing a sector search pattern.

4. Sector Multiunit Radar (VMR). This pattern is used when a radar-equipped marine craft takes station at the center of the pattern and provides radar navigation assistance to two or three search aircraft in completing a sector search pattern. Vertical separation must be maintained.

i. Contour Patterns (O)

There are two forms of contour search patterns: OS and OM. These patterns are used for search in mountainous and hilly terrain. They can also be adapted for use by underwater SRU's for searching peaks on the ocean floor.

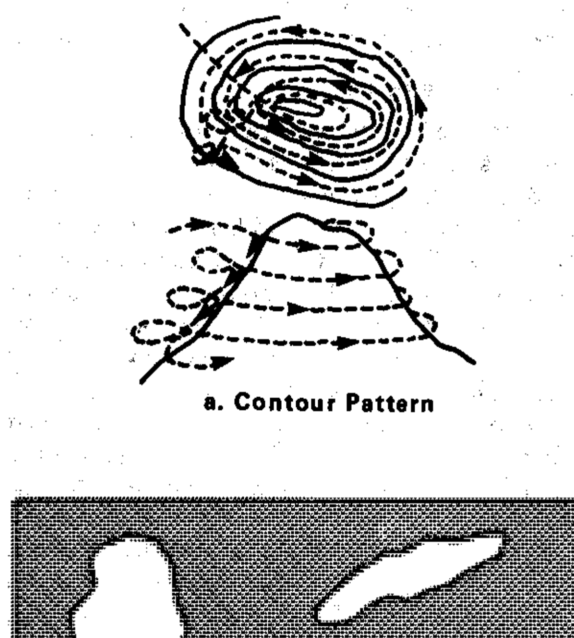
1. Contour Single-Unit (OS). Only one search aircraft is assigned in any one area for contour searches. The search is started above the highest peak and the aircraft flown around the mountain "tucked in" closely to the mountain side. As one contour circuit is completed the altitude is normally decreased 500 feet (descending 360° turn opposite to direction of search pattern) and a new contour circuit commenced.

It cannot be too strongly emphasized that contour searches are extremely dangerous unless the following conditions are satisfied:

(a) The crew is experienced, well briefed, and possesses accurate large scale maps indicating contour lines.

(b) Weather conditions are good regarding both visibility and lack of gustiness.

(c) The aircraft engaged is suitable, i.e., highly maneuverable, has a steep climbing rate, and a small turning circle.



a. Contour Pattern

b. Contour Search Record

FIGURE 8–54

(d) The search is started above the highest peak.

Crews should exercise extreme caution when searching in canyons and valleys. Valleys where it may be impossible to either climb out, or effect a turn around, should be indicated to them.

It is necessary that an accurate record be kept of the area searched. There will invariably be some mountain peaks and valleys shrouded in clouds which will have to be searched later when conditions permit. Actual search coverage should be plotted by the aircrew as tracks are flown. The approved method of recordkeeping is to shade in the area searched and outline areas unsearched on a large scale topographical map, as depicted in figure 8–54b.

2. Contour Multiunit (OM). Multiunit contour searches are *only conducted by land search teams.* This procedure is adopted when hills, peaks, razorbacks or other mountainous features can be completely encircled. The search is commenced with one flanker at the highest level and the other at the low end of the line. Upon completion of the encirclement the line is reformed on the lower side of the lower flanker and the process repeated until the search is concluded.

j. Flare Patterns (F)

There are two forms of parachute flare search patterns: FS and FM. These patterns are only used at night. Detection of survivors at night who have no night visual aids is purely a matter of chance. The use of aircraft parachute flares does not appreciably increase the chance of detection. It has very limited potential in searches for anything other than large objects located in well-defined search areas on flat land or at sea. Nevertheless, instances have occurred where small objects and lone survivors have been found with the help of this type of illumination.

Parachute flares should be used for searches over land areas only when the situation is so urgent that the risk of starting ground fires can be accepted. They are, in any case, of more use in sea searches where it is less likely that an observer searching under parachute flare illumination will be confused by silhouettes or reflections from objects other than the search target.

Parachute flares are normally dropped from a fixed wing aircraft flying above and ahead of the search unit. In this type of search, the most efficient search unit is the vessel, next the helicopter, with the fixed-wing aircraft a very poor third.

1. Flare Single–Unit (FS). If this pattern is carried out by a single ship with an aircraft dropping flares, the pattern looks like figure 8–55. Only large targets on or near the ship's track will stand a reasonably good chance of detection. Highest illumination would occur at the point where a flare was over the vessel. However, the aircraft should drop the flare so that it passes, near, but not over, the ship during the middle of the burning period. Some flare models drop casings when they are launched, then when the burning period is completed, the parachutes are collapsed and the assemblies free-fall to the surface. Precautions must be taken to avoid dropping any flare parts on the ship.

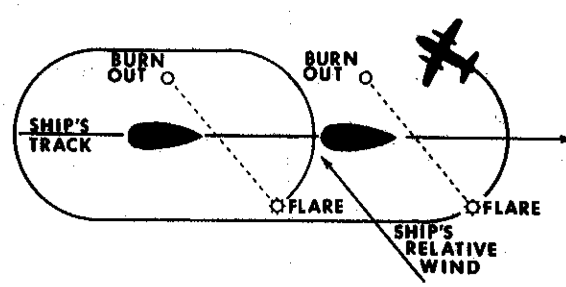


FIGURE 8–55

If this pattern is carried out by a helicopter and a fixed wing aircraft, it must only be conducted over water and in visual meteorological conditions. The pattern will look like figure 8–56. In this case the search helicopter flies at a minimum altitude of 500 feet and, whenever possible, the search should be oriented to fly legs into the wind and downwind. The fixed wing aircraft drops flares at the 2 o'clock or 10 o'clock position of the helicopter, and at a height which permits the flare to burn out at or below the helicopter's altitude.

CAUTION: Flares must never be dropped in such a way that the flare or its casing and parachute pass directly over the helicopter.

Illumination for a helicopter search must be continuous because alternations between light and darkness tend to cause orientation problems for the helicopter pilots. The pattern must be planned so that the fixed wing aircraft is in position to drop a new flare just before the old one is burned out. The strength of the wind must be considered. Ideally the flares should be dropped so that they ignite at the 2 o'clock or 10 o'clock positions and burn out at the 4 o'clock or 8 o'clock positions. Illumination may be on one or both sides of the helicopter.

Once the helicopter crew has made a sighting and begins to maneuver to investigate, the pattern will be discontinued. The let-down/hover approach procedures will vary with the type of helicopter and standard operating instructions of the parent agency. Whether or not illumination will be provided during the approach to a hover and pick-up maneuver should be at the discretion of the helicopter pilot and should be determined in advance. If illumination is desired during the approach and pick-up, it must be continuous and care must be taken to prevent the flares from drifting over the helicopter.

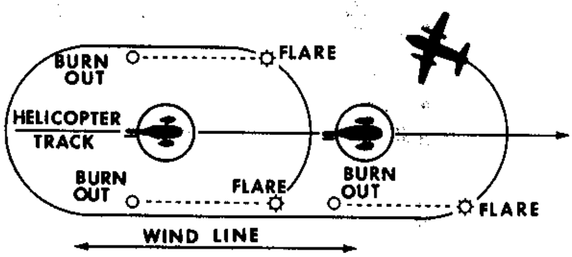


FIGURE 8-56

2. Flare Multiunit (FM). This procedure is essentially similar to the Parallel Track Multiunit Nonreturn pattern. The vessels form a line abeam formation with the spacing between the ships depending on the size of the target and on local conditions. The aircraft flies a "racetrack" pattern over the formation, dropping a set of flares upwind so that they are over the formation during the middle of the burning period and a new set is dropped as the previous set burns out. The number of flares to be dropped will depend on the length of the line of vessels.

If the length of the line of vessels is long, the aircraft may have to adjust the pattern to make continuous illumination possible. The aircraft can make 80–260 course reversal and start dropping flares at the opposite ends of the pattern for each set dropped.

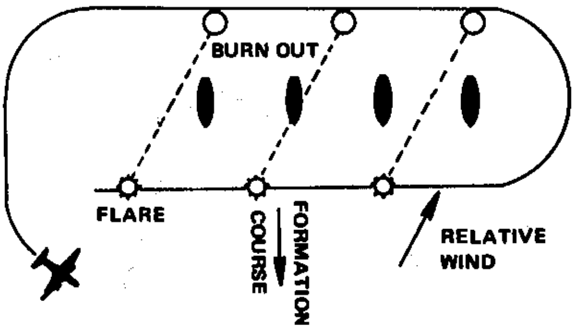


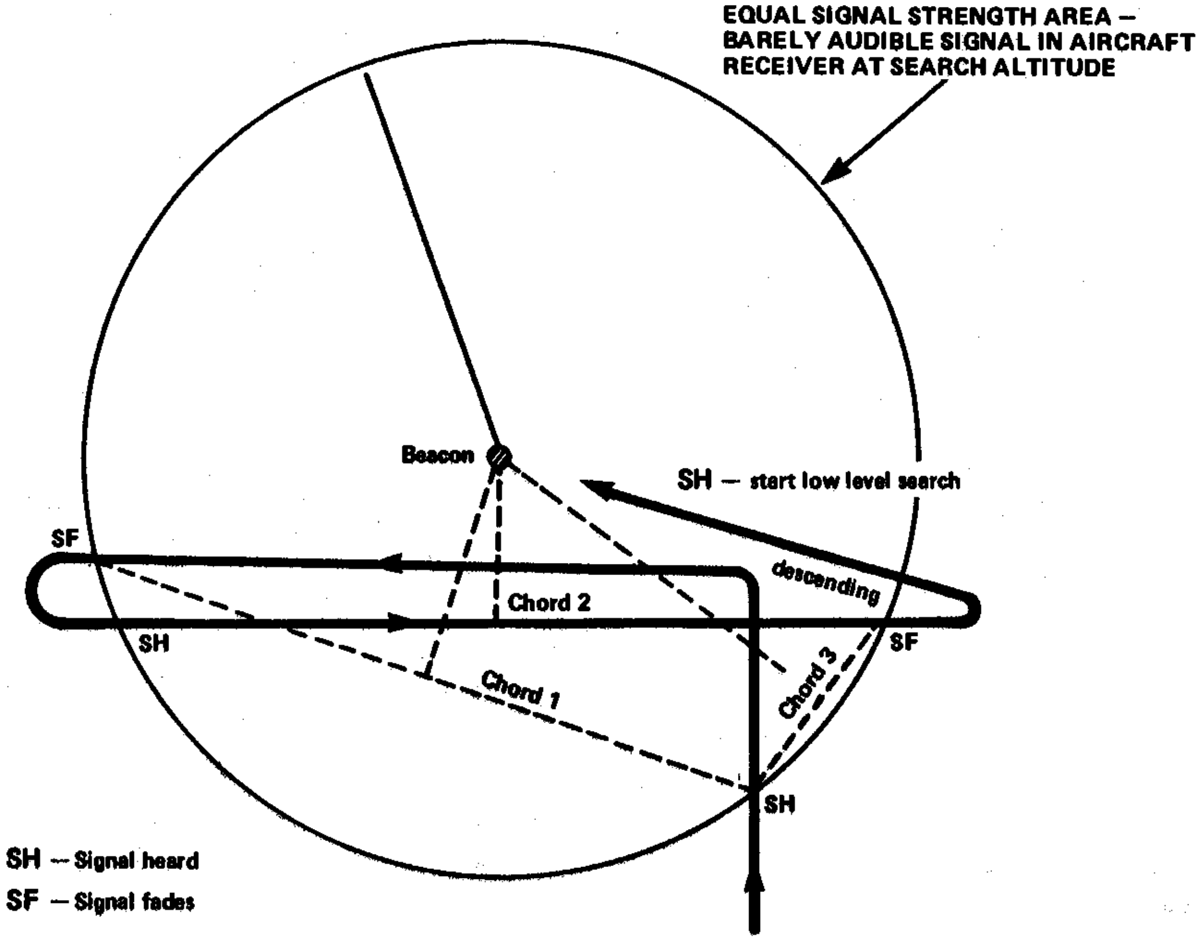
FIGURE 8-57

k. Homing Patterns (H)

There are three forms of homing patterns: HSA, HSM, HMN. These patterns are used to locate emergency locater transmitters or other radio/electronic emissions from survivors or distressed craft. They are designed for use when the detected signal is too weak for installed homing equipment to receive, or if the search craft does not have homing equipment.

1. Homing Single-Unit Aural (HSA). In this procedure the aircraft flies a "boxing-in" pattern on the assumption that the area of equal beacon signal strength is circular. The position of the aircraft is plotted as soon as the signal is heard for the first time. The pilot continues on the same heading for a short distance, then turns 90° to either port or starboard and proceeds until the signal fades. This position is noted. He now turns 180° and once again the positions where the signal is heard and where it fades are noted. The approximate position of the beacon can now be found: first, by drawing chord lines between each set of "signal heard" and "signal fade" positions and then by drawing the perpendicular bisectors of each chord. The aircraft now proceeds to this position and descends to an appropriate level for sighting (e.g. below cloud). However, since the area of equal signal strength on which this procedure is based is seldom, if ever, circular, the triangle produced by the bisectors will give only an approximate position so that another close-in search must be made. This may either be another aural search, or a visual search (e.g. sector search) using the approximate position as a datum point.

2. Homing Single-Unit Meter (HSM). In this procedure the signal of the beacon is measured



HSA Pattern

FIGURE 8–58

on the signal strength meter of the receiver. On the initial heading of the aircraft into the search area, two positions of equal meter reading are plotted and the mid-point between the two determined. (This point will coincide with the point of maximum signal strength, if it were possible to locate it accurately.) The pilot now turns the aircraft 180° and upon reaching the mid-point makes a 90° turn to either port or starboard. If the signal fades he is obviously heading in the wrong direction and turns the aircraft onto the reciprocal. Two points of equal meter reading are also plotted on this heading. This time the point of maximum reading, if accurately established, is also the location of the beacon. After passing the second point of equal reading the pilot makes a 180° turn and descends to an appropriate altitude. It has been found that this method of search, if carefully executed, is very accurate and can make a further search unnecessary.

3. Homing Multiunit Nonreturn (HMN). This pattern is used to obtain useful data from en route aircraft without requiring them to divert from their tracks. Aircraft passing near the suspected area of distress are asked to listen on the beacon frequency and report the positions where the signal was first heard and where it was lost. If the aircraft are meter-equipped, they are asked to report two positions of equal meter readings.

By plotting perpendicular bisectors of all reported position pairs, the SMC can narrow the possibility area greatly and in some cases can

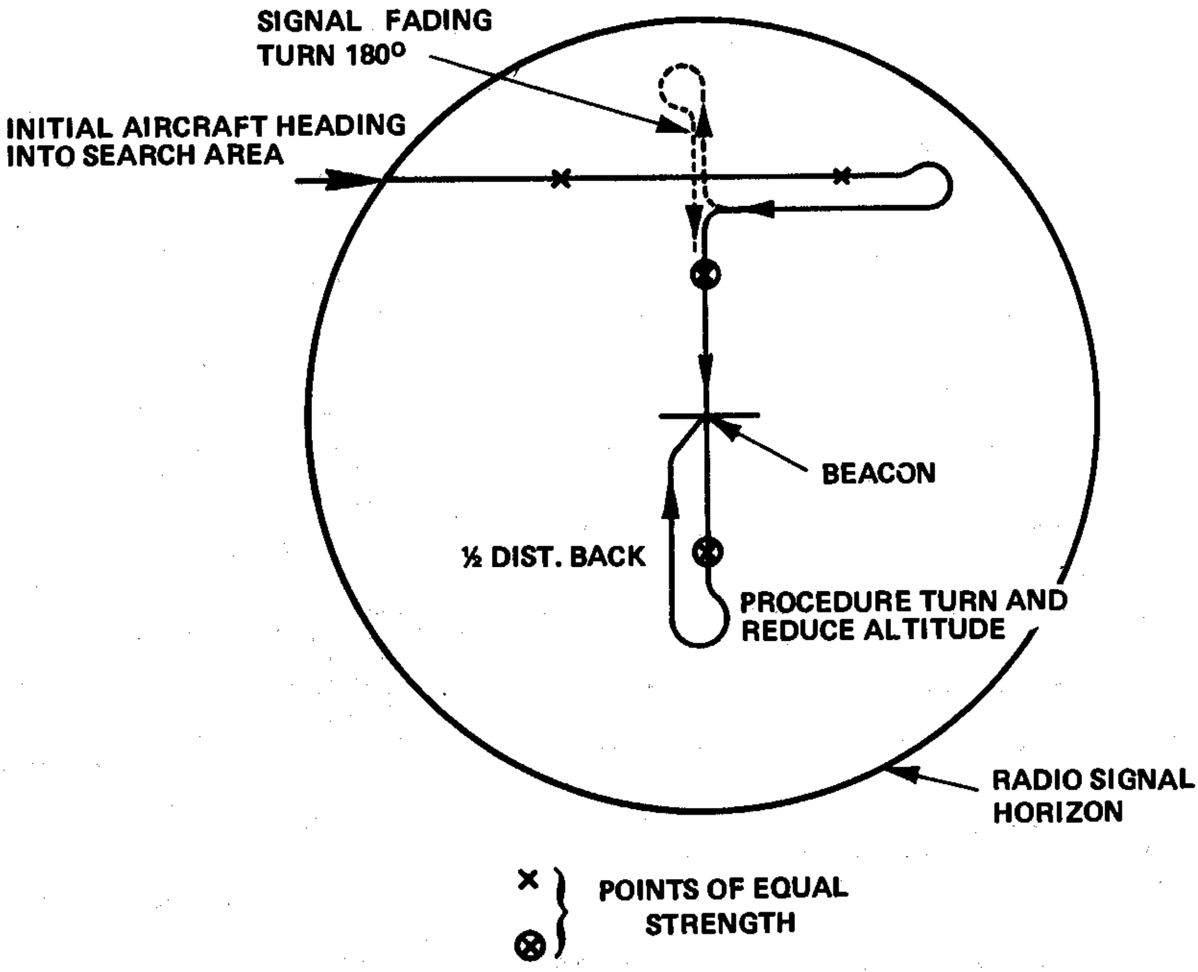


FIGURE 8–59

establish the survivors position with reasonable accuracy. This procedure is very useful in areas of regularly transiting aircraft.

833 Search Pattern Selection

Figure 8–60 summarizes the search patterns, lists minimum required search units, and provides brief remarks concerning their particular advantages or applicability. Often only one type of search pattern will be used. In other cases, several search patterns will be used simultaneously, but in different search areas. And in still other situations, a series of different search patterns will be used in sequence for the same search area. Obviously, the SMC must have a thorough, detailed knowledge of every search pattern available for SAR operations, if he is to select the most appropriate pattern for his particular circumstances.

Search Pattern Summary

Pattern	Name	SRU required	Remarks
TSR	Trackline single-unit return	1	For search of a trackline or line of position when unit must break off search at same end of track as search originated.
TMR	Trackline multiunit return	2 or more	Same as TSR except that 2 or more SRUs are used cruising abeam of each other.

(Continued)

Pattern	Name	SRU required	Remarks
TSN	Trackline single-unit nonreturn	1	Same as TSR except that search terminates at opposite end of track from commence search point.
TMN	Trackline multiunit nonreturn	2 or more	Same as TMR except that search terminates at opposite end of track from commence search point.
PS	Parallel track single unit	1	Search of a large area when positoin of distress is unknown.
PM	Parallel track multiunit	2 or more	Same as PS except two or more SRUs search abeam of each other a distance S apart.
PMR	Parallel track multiunit return	do	Used for search of long rectangular area where only one track out and back is possible.
PMN	Parallel track multiunit nonreturn	do	Only enroute SRUs or transient craft available for one track through search area.
PSL	Parallel track single-unit Loran line	1	Same as PS except SRU uses Loran lines for greater navigational accuracy on tracks.
PSA	Parallel single-unit arc	1	DME, Tacan, or Vortac must be available in area.
PSC	Parallel single-unit circle	1	Distance measuring navigation system must be available in area. Common underwater pattern.
PMC	Parallel multiunit circle	2 or more	Underwater pattern only.
PSS	Parallel single-unit spiral	1	Underwater pattern only.
CS	Creeping line single unit	1	Distress generally known to be between two points. Wider than trackline patterns.
CM	Creeping line multiunit	2 or more	Same as CS except that two or more SRU are used cruising abeam of each other.
CSC	Creeping line single unit coordinated	1 acft + 1 ship	Same as PS except coordinated ship movement used to obtain greater navigational accuracy.
CMC	Creeping line multiunit coordinated	2 acft+1 ship	Same as CSC except 2 search aircraft are used cruising abeam of each other.
CSR	Creeping line single-unit radar	1 acft+1 ship	Same as CSC except that ship controls aircraft by radar to keep aircraft on search tracks.
CMR	Creeping line multiunit radar	2 acft+1 ship	Same as CMC except that ship controls aircraft by radar to keep aircraft on search tracks.
CMCS	Creeping line multiunit coordinated split.	2 acft+1 ship	Used when large speed differential exists between the two aircraft.
SS	Square single-unit	1	Distress position known within close limits and search area not extensive.
SM	Square multiunit	2	Same as SS pattern but both SRUs search independently, with tracks 45° apart.
VS	Sector single unit	1	Distress position known within close limits and search area not extensive.
VM	Sector multiunit	2 or 3	Same as VS except two or three SRUs are used.
VSR	Sector single-unit radar	1 acft+1 ship	Same as VS except ship controls aircraft by radar.
VMR	Sector multiunit radar	2 or 3 acft+1 ship	Same as VM except ship controls aircraft by radar.
OS	Contour single-unit	1	Search of mountainous/hilly terrain.

(Continued)

Search Pattern Summary—Continued

Pattern	Name	SRU required	Remarks
OM	Contour multiunit	2 or more	Ground search of mountainous/hilly terrain.
FS	Flare single unit	1 acft+1 ship or 2 acft.	Night visual search only.
FM	Flare multiunit	1 acft+ships	Night visual search only.
HSA	Homing single-unit aural	1	Electronic homing-in use.
HSM	Homing single-unit meter	1	Electronic homing-in use.
HMN	Homing multiunit nonreturn	2 or more	Electronic positioning use.

FIGURE 8–60

Generally, the following factors will have the greatest influence on which particular search pattern will be selected by the SMC:

(a) The known accuracy of the distress position.

(b) The size and shape of the search area.

(c) The number and type of SRUs available.

(d) The enroute and on scene weather.

(e) The distance between the search area and the SRU departure base.

(f) The availability of navigation aids in the search area.

(g) The size and detectability of the search target.

(h) The desired probability of detection.

(i) The limitations of time.

(j) The limitations of terrain.

Time permitting, the search patterns being considered for use should be listed with their advantages and disadvantages and then compared. From this comparison, the search pattern is selected which best suits the mission circumstances. The selected pattern is then examined for suitability, feasibility, and acceptability. A search pattern is suitable if it will accomplish the mission within the existing time limitations; it is feasible if it can be executed with the SRUs, available in the face of weather, distances, and similar limitations existing at the time; it is acceptable if the results expected from its execution will be worth the estimated effort and cost.

During large scale searches, ample time is usually available for the SMC to thoroughly plan his search efforts. It is essential that careful thought go into the selection of search patterns and into the designation of specific search units to execute the patterns. Once large scale search efforts are underway, redeployment of search units or changing of assigned search patterns becomes exceedingly difficult. Therefore, even if time does not permit a written analytical comparison of the various, possible search patterns, the SMC must mentally consider and evaluate their individual features before making his selection.

840 AREA COVERAGE

Search area coverage involves the systematic search of selected areas to obtain the optimum probability of detecting a search target. Many factors influence detection capability during a search, and these factors are seldom identical in any two situations. The relative influence of these factors can be predicted to some extent. If the SMC is aware of them, his search planning and the search operation will be more effective. These factors can be reduced to four related mathematical expressions which simplify the employment of search units. These factors are:

S—Track spacing.

P—Probability of detection.

W—Sweep width.

C—Coverage factor.

These expressions may be broadly considered as measurements. In this sense, S is a general measure of search effort; P is a measure of search results—either desired or attained results; W is a measure of detection capability; and C is a measure of search quality.

841 Track Spacing (S)

Track spacing (S) is the distance between adjacent search tracks. These tracks may be produced by the simultaneous sweeps of several searching units, as depicted in figure 8–

61A or by the successive sweeps of a single searching unit, as depicted in figure 8–61B.

The probabilitv of detection can be increased by decreasing the track spacing. In other words, the closer the search tracks are to each other, the higher will be the probability for detecting the target. However, whenever the track spacing is decreased, more time will be required to complete the search of a given area with the same number of SRUs. If the extra time is not available to the SMC, and he still desires to increase the probability of detection by reducing the track spacing, then he has no other choice but to accept a smaller area that can be searched. This is assuming that no additional search units are available.

There is also a limit to which the track spacing can be reduced. This is due to the practical limits of navigational accuracy by the search units. The optimum track spacing is that which permits the maximum expectation of target detection in the available time or that is consistent with the economical employment of the available search units.

Track spacing (S) is expressed in yards for ground party searches and underwater searches; it is expressed in nautical miles for other types of searches described herein.

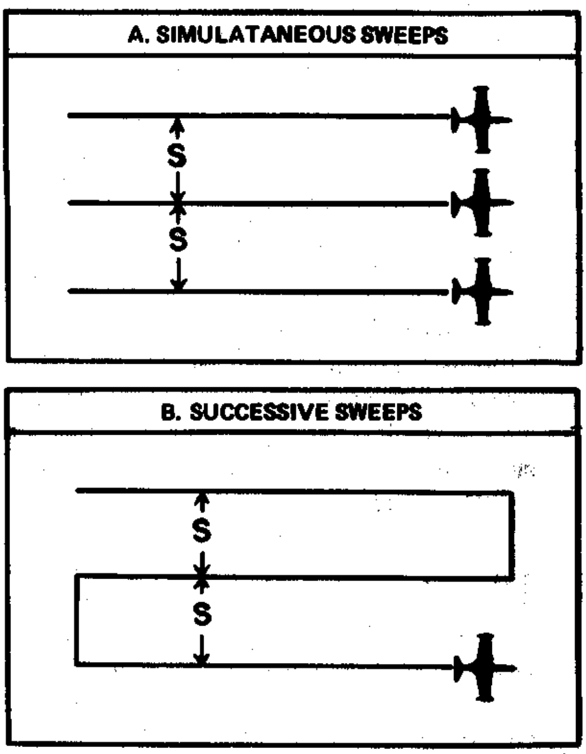


FIGURE 8–61

842 Probability of Detection (P)

A search planner may use the probability of detection (P) as a measure of search results. It may be used to express the search results desired before the search is started, or it may be used to express the search results obtained after one or more searches are completed. Any estimate of a success probability is simply a statement of the proportion of successes expected when some operation is repeated many times.

Although P is usually expressed as a percentage, keep in mind that it is really stating the odds of success or failure for detecting the search target. For example, a 67% probability of detection is just another way of stating that the odds are two out of three for success, or that the odds are two to one for success. Suppose the SMC calculated the detection probability to be 90%. He would expect that the search target would be detected nine times out of ten, on the average. And conversely, he would expect one failure for every nine successes. Thus occasional failures to detect survivors is understandable and consistent with high values of calculated probabilities for successful detection.

A definite probability for detecting a search target exists for each scan made by the search unit's scanners, lookout, or detection equipment. This probability is called the instantaneous probability of detection. This instantaneous probability of detection, repeated with successive scans as the search unit moves along the track, develops the probability pattern of the search. The instantaneous probability of detection is not uniform across the swept area. In general, it is highest at short distances from the search unit, and decreases as the distance from the search unit increases. Figure 8–62 depicts a typical curve for instantaneous probability of detection versus lateral range. Close to the observer, the probability of detecting the search target is high. As the range increases away from the observer, it decreases until it is zero at the maximum detection range for that particular target. Detection range is measured from the position of the observer in the direction of scan.

If a second observer stands back to back with the first observer (or if the first observer alternates his scan 180 degrees), the resultant in-

Instantaneous Probability of Detection Versus Lateral Range

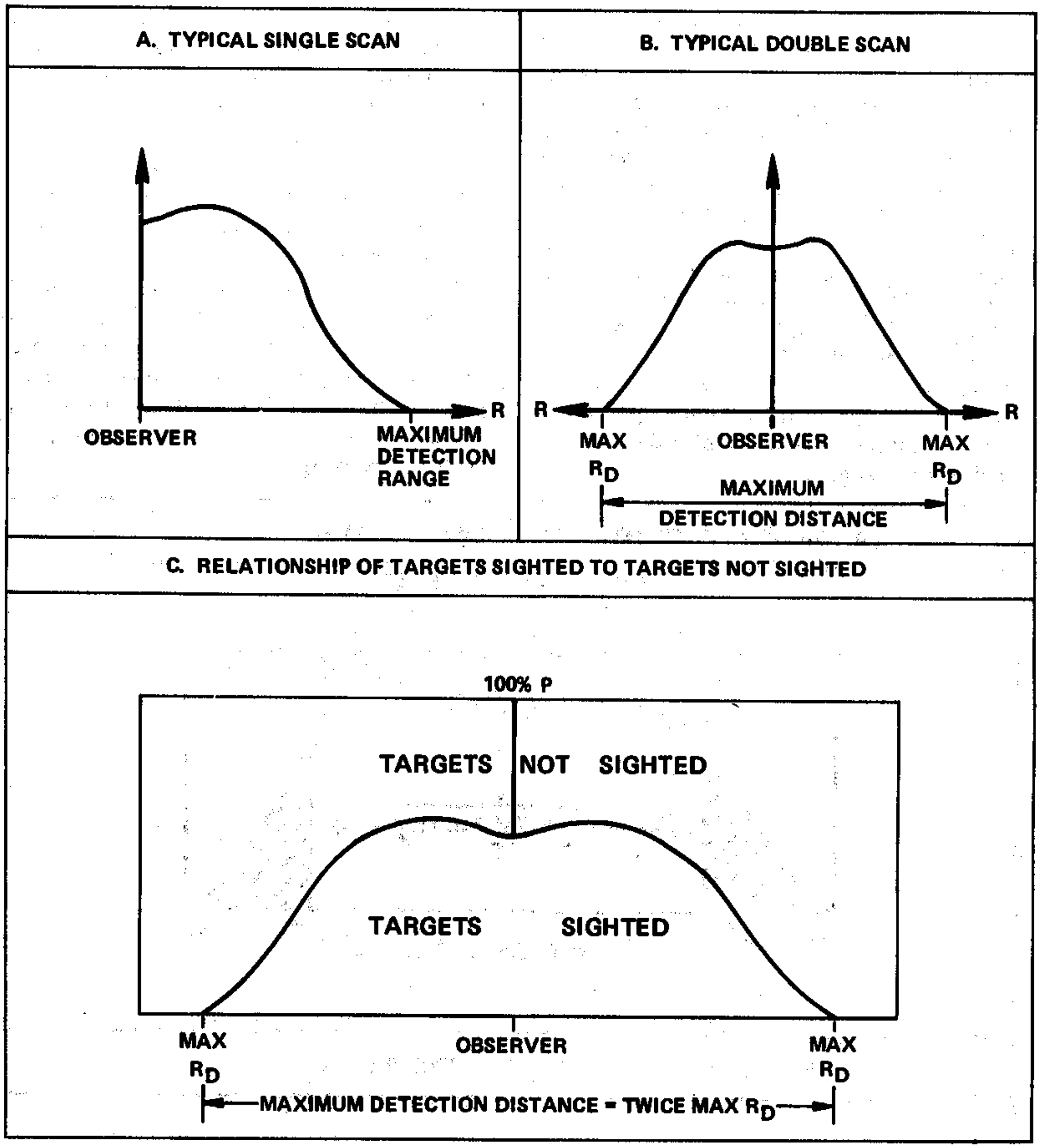


FIGURE 8–62

stantaneous probability of detection curve would be as shown in figure 8–62B. This is the typical curve for search craft since scanners or detection equipment normally search on both sides of the search craft simultaneously.

Note that the curves are not straight lines between the observer and the maximum detection range. This graphically illustrates that the probability is not uniform, and does not have a constant rate of decrease as the range is increased away for the observer. Also note the slight decrease in probability at very close ranges. This is due to such factors as the adverse close range effects of sea return during radar searches, pinging over the target during sonar searches, aircraft fuselage blocking scanners' view of surface underneath the aircraft, vessel superstructure or hull blocking lookouts' view of water surface close aboard, etc.

Suppose a large number of identical targets were distributed along a line uniformly (equal distances apart). The observer is placed at the midpoint of the line and makes a double observation as depicted in figure 8–62B. He will sight most of the targets which are at close range; less targets at greater ranges; and no targets beyond the maximum detection range. Figure 8–62C depicts the uniform distribution of targets (the rectangle) and a typical instantaneous probability of detection curve superimposed upon it. This graphically demonstrates the relationship of targets sighted (within the curve) to targets missed (outside the curve but inside the rectangle.)

The ratio of targets actually sighted to the total number of targets that are present will obviously vary with the range from the observer. Also if we multiply this ratio by 100, this will provide us with the instantaneous probability of detection as a percentage. However, we will have to specify a particular range from the observer since this instantaneous probability curve is not uniform, that is, it is not a constant value at all ranges.

In order to overcome this lack of uniformity, we use the concept of sweep width, which reduces the detection capability for a given sweep to a single numerical value. In other words, the sweep width is merely a single number summation of the more complex range detection probability relationship.

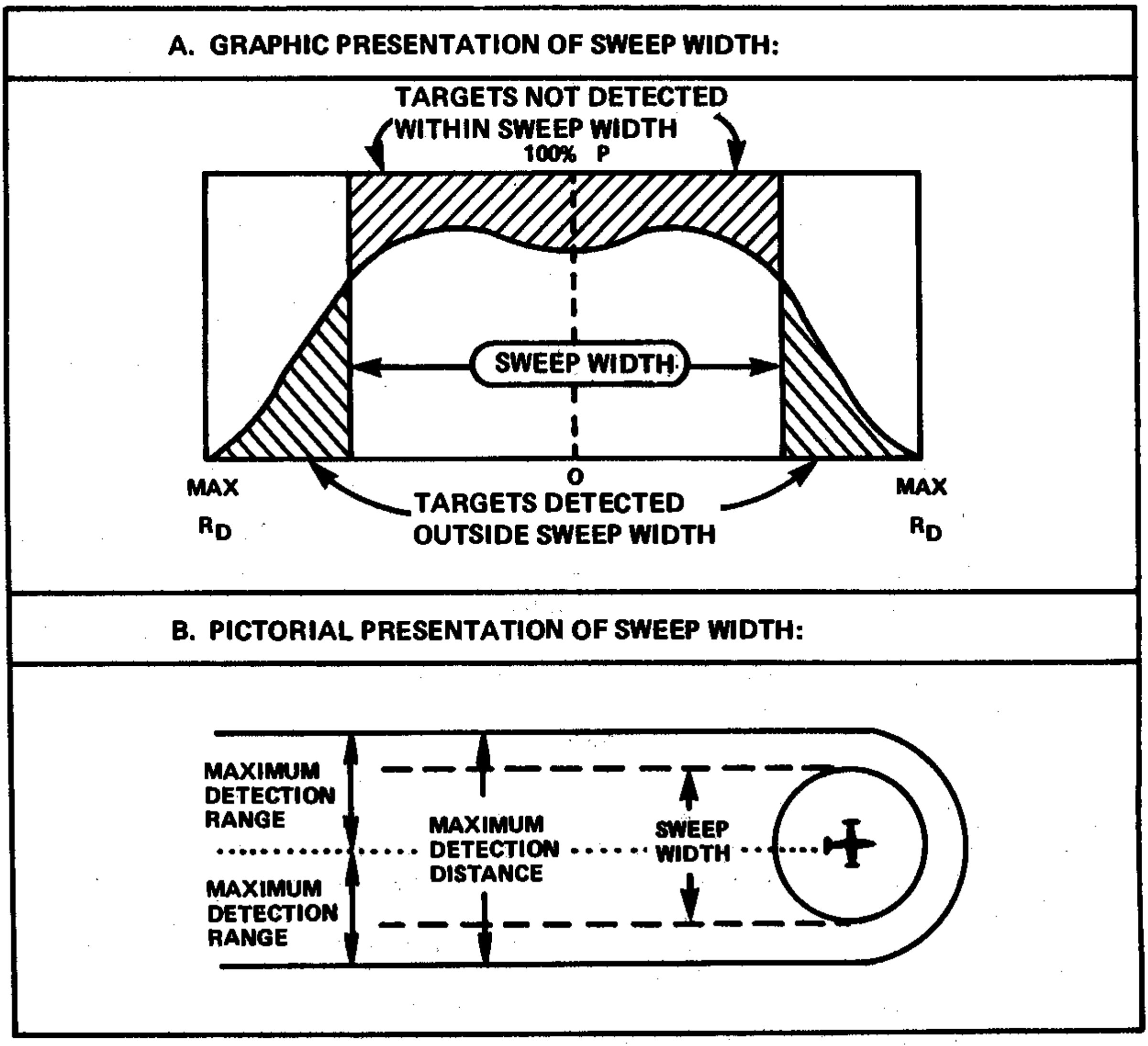


FIGURE 8–63