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LAND NAVIGATION

8.0 GENERAL

Any GSAR task will employ at least some of the land navigation techniques described in this chapter. Land navigation skills may well be the key to survival in some outdoor emergencies; therefore, every GSAR team member should take care to learn and maintain his or her personal land navigation skills, for personal survival value, if for no other reason.

Land navigation is an art requiring knowledge of the proper use of map and compass. However, this alone is not sufficient; good land navigation also requires the ability to apply navigation concepts in the field. No amount of practice with map or compass alone will guarantee proficiency in land navigation. Cross country travel with map and compass is perhaps the best way to become proficient, and Orienteering (described below) is an ideal way to get this experience.

This chapter will discuss maps and grid systems, compasses, Orienteering, and several specific navigation techniques. The chapter is designed for a reader having studied the U. S. Geological Survey pamphlet "Topographic Maps", or having equivalent knowledge.

8.1 TOPOGRAPHIC MAPS AND GRID SYSTEMS

8.1.0 General

Maps are necessary for any land navigation. A map is defined as a symbolic representation of the terrain features of a given area, and it may take one of many forms. A mental map derived from past experiences, a pencil sketch and verbal description, or an aerial photograph, all could be used for navigation. However, the best map for general land navigation on foot is one of the <u>topographic maps</u> put out by the U. S. Geological Survey (USGS). Such maps are available for all of Virginia.

A common problem in ground search and rescue is the accurate transmission of geographic position information using voice communications (e.g. radio). To facilitate this process, various systems have been developed for reporting position, most of which are grid systems. Although there are a great many such systems in use, only those of major importance to GSAR personnel will be presented here. These are:

1. <u>The Latitude and Longitude System</u>. Although this is the oldest and most widespread method of indicating position, it is not useful for GSAR, as accuracy of a hundred meters may be vital to GSAR teams. An understanding of it is essential to most other grid systems used for SAR, and it may be used as a reliable but slow last resort.

2. The "Second G in George Washington" System. This system works only when the same map is available at both ends of a communications link. The position is specified by referring to details printed on the map. For example: "We are at a point on the 1580 foot contour line where an intermittent stream crosses it, which is about $2\frac{1}{2}$ inches northeast of the second G in the words George Washington National Forest where they are printed in the top left corner of the map." This system, if it can be called a system, is cumbersome, subject to error, and useful only when a large supply of identical maps are available.

3. <u>The Uniform Map System (UMS)</u>. This system is the "official" SAR grid system, such that there can be an official system, and it incorporates the grid system long used by the CAP. It requires the use of pregridded maps, but is quick and easy to use. It is primarily used for downed aircraft search, and is described in section 8.1.2.

4. Lost Person Search Gridding. Lost person search operations are usually confined to a relatively small area. For position reporting during such missions, accuracy is essential, and none of the systems described above can provide such accuracy without becoming complex and confusing. Field Team Leaders are usually provided with a photocopy of a portion of a $7\frac{1}{2}$ quad, and it is common practice to put a 100 meter grid on the photocopy map, by means of a gridded overlay. Every Field Team Leader, and Base Camp, then has a common large-scale grid system for accurate position reporting.

5. <u>Position and Azimuth (Bearing)</u>. Pilots may give GSAR teams position coordinates in terms of an azimuth (a compass direction, or bearing) and distances; or in the form of several azimuths to be used for resection (see section 8.7.2). Such azimuths are usually given from navigational aids called <u>VORs</u>, which are named and identified on aeronautical charts (sectional charts), but not shown on most other types of maps.

8.1.1 Topographic Maps

Topographic maps ("topo maps") provide information as to the actual shape of the land surface by means of brown <u>contour lines</u>. At first glance, these lines will probably seem meaningless or confusing to the untrained map reader. However, to one used to such maps, the contour lines provide a wealth of information, and make the terrain "leap out" as if he were looking at a scale model of the area. Rapid interpretation of contour lines takes practice, but the skill is easily retained.

The USGS publishes a folder entitled "Topographic Maps" which serves as an excellent introduction and reference to topographic maps, and which is available from the USGS at little or no cost. The reader is urged to refer to it at this point, as the remainder of this chapter will assume familiarity with its contents.

Every 7'30" x 7'30" quadrangle $(7\frac{1}{2} \text{ quad})$ has certain border information which is of great importance. As an example, we will consider the Waynesboro East $7\frac{1}{2}$ quad, shown in Figure 8-1. Explanation of the relevant border information is given below.

1. <u>Name</u>. Each map is designated by a unique place-name, a series, (e.g. $7\frac{1}{2}$ minute topographic series), and by the state(s) which have land shown on the map. This information is found in the upper right corner.

2. <u>Date</u>. In the lower right corner, the map name is reproduced, along with some index numbers. A map date is given, which represents the completion date of the map. (See also number ?).

3. <u>Road Classification</u>. Directly above the name and date (number 2), a key to the road symbols is given. This is <u>not</u> the complete topographic map legend; the legend is issued separately, and is shown also on pages 20-21 of "Topographic Maps."

4. <u>Scale</u>. At the bottom center of the sheet, the map scale is indicated in two ways. First, the ratio of map distance to actual distance is given, 1:24,000 being standard for $7\frac{1}{2}$ quads. Second, a graphic scale of miles, feet, and kilometers is displayed. Directly under the scale is notation of the <u>contour interval</u> used.

5. <u>Contour Interval</u>. The contour interval is the elevation difference between adjacent contour lines. If additional supplemental (dotted) contour lines are used, their use is usually shown here.

6. <u>Declination</u>. A set of three arrows is shown, which indicate the directions of grid north (GN), magnetic north (MN), and map ("true") north (star). <u>These arrows</u> indicate a general direction only and should not be used for orienting a map. The measure of each declination angle (true-magnetic and true-grid) is provided in de-



grees and in mils. (There are 6400 mils to 360°.) For this map, the magnetic declination is 6° West, meaning that magnetic north is six degrees west (counterclockwise) of true or map north. Note that grid north and map north are <u>not</u> the same; map north is "true" north, and the edges of the map are lined up map north-south and map east-west. Grid north refers to north in the Universal Transverse Mercator (UTM) grid system, which is no importance for routine land navigation. Also, the phrase "at center of sheet" under the arrows serves to remind us that declination may vary from one part of a map to another. In Virginia, this variation across a map is usually a small fraction of a degree, and may be ignored for our purposes. However, large changes in declination may be brought about by the presence of a ferromagnetic body, such as an outcrop of iron ore, a scrap of metal on the ground, or a belt buckle brought near the compass.

7. <u>Mapping Information</u>. This information expands on the bare fact of the map date, providing information as to when and how the mapping was carried out. Additional information concerning the map is often given here.

8. <u>Edge Information</u>. Around the edge of the map are blue and black "ticks" which key the map to the UTM and Virginia grid systems, respectively. These are of little importance for GSAR. Shown also are markings and ticks indicating latitude and longitude; care should be taken not to confuse the latitude/longitude ticks with those for the two grid systems.

9. <u>Key to Adjacent Maps</u>. In the center of each side of the map, and at each corner, a map name is printed in parentheses and italics. This provides the map user with the names of all surrounding quadrangles.

8.1.2 Latitude and Longitude

The coordinate system for the earth's surface known as <u>latitude and longitude</u> has international acceptance. The words are Latin: Romans referred to the direction along the axis of the Mediterranean Sea as longitude, and the direction across it as latitude. Latitude now refers to a point's north-south position on an arc (actually, close to a half-circle) drawn from the north pole to the south pole. All such arcs may be divided into degrees, as can any part of a circle, and there are therefore 180 degrees (180°) in each such arc. (There are 360° in a full circle.) The latitude of 0° is arbitrarily set at the equator, and latitude is described as being north or south of the equator. Thus 90° north is at the north pole, and 90° south is at the south pole. If all points of equal latitude were to be connected by a line, a circle would result which is referred to as a parallel. An example of this is shown in figure 8-2a.

If any line of latitude describes a circle, then we may again use degree measure to refer to points on this circle. For reference, all points along a north-south arc through Greenwich, England are referred to as being at a longitude of 0°. This north-south line of 0° longitude is referred to as the <u>Prime Meridian</u>, and all other north-south lines are referred to as meridians, as shown in figure 8-2b. Longitude is measured in degrees east or west of Greenwich; therefore, 180° east and 180° west both describe the same meridian, which is at the exact opposite side of the world from the Prime Meridian going through the Royal Observatory at Greenwich.

A location may then be totally and precisely located by its latitude and longitude, as illustrated in figure 8-2c. When locations must be specified to greater accuracy than one degree, divisions of degree measure called <u>minutes</u> and <u>seconds</u> of latitude and longitude may be used. One degree may be divided into 60 minutes, and one minute may be divided into 60 seconds, or $1^{\circ}=60'=360''$.



a. Latitude 38° North



c. Latitude and longitude 38°N 79°W



FIGURE 8-2: Latitude and longitude

b. Longitude: Prime Meridian (0°) and 25° West meridian

8.1.3 The U. S. Geological Survey Topographic Map Series

The United States Geological Survey (USGS) publishes maps, including the topographic series. Topographic maps are published at three primary scales which may be encountered by GSAR personnel.

<u>1:250,000 Series</u>. These maps cover an area $1^{\circ} \ge 2^{\circ}$, at a scale of approximately one inch to about four miles. Most such maps for Virginia are not up to date as far as road and culture information are concerned, and are not very useful for localized search operations due to the small scale. As a supplement to a state highway map, they are very useful in downed aircraft search operations.

<u>15' Quadrangle Series ("15 minute quads")</u> are published at a scale of 1:62,500, or approximately one inch to a mile. Each quad covers an area 15' by 15', as may be inferred by the name. These maps are quite useful for many types of search operations, as the scale is large enough to be of use in small area operations such as lost person search, but small enough in scale to be useful for search operations covering a larger area. Unfortunately for GSAR teams, the USGS is gradually replacing all 15' quads with $7\frac{1}{2}$ ' quads, and few 15' quads are still available for Virginia.



FIGURE 8-3: Relative Coverage of 3 USGS Topographic Map Series Sizes. A: 1:250,000 Series (1° x 2°) B: 15' x 15' Quadrangle Series (1:62500) C: 7'30" x 7'30" Quadrangle Series (1:24000)

 $\frac{7\frac{1}{2}}{2}$ Quadrangle Series (" $7\frac{1}{2}$ ' quads") are published at a scale of 1:24,000, or about $2\frac{1}{2}$ inches to the mile, and are available for most of Virginia. These maps are quite detailed, and are ideal for lost person search or close-in downed aircraft search. One problem with $7\frac{1}{2}$ quads is that they are somewhat unwieldly when more than one is required, as it is often difficult to find space to spread them out in the field. Another problem is that although it takes four $7\frac{1}{2}$ quads to cover the same area covered by a 15' quad, the cost of an individual map is the same. Acquiring enough $7\frac{1}{2}$ quads to cover an area can be quite a financial burden to a GSAR team.

The relative coverage and shapes of each of these series is illustrated in figure 8-3.

8.1.4 The Uniform Map System (UMS)

The Uniform Map System (UMS) is the official SAR grid system. CAP members are fortunate in that this system incorporates the standard grid system used by the CAP for years.

The UMS is based on the standard Sectional Aeronautical Chart (scale 1:500,000). Each chart is gridded into 15' x 15' quadrangles, and each quadrangle is assigned a number, from left to right and top to bottom, across the chart. Each quadrangle, or "grid" as it is usually called, may be further subdivided into four quadrants, although this is not usually done on sectional charts. Each quadrant is assigned a

letter as shown in figure 8-4a. Thus, any individual 7[±] quad in the country may be specified by (1) a sectional chart name or abbreviation, (2) a number up to three digits, and (3) a letter. Thus the X in figure 8-4a may be referred to as being in grid Washington 314B. Further specification of position is provided by specifying the distance in miles from the nearest 15' (as opposed to $7\frac{1}{2}$ ') quadrangle corner. giving the horizontal (east-west) distance first, then the vertical (north-south) distance next. This is illustrated in figure 8-4b, where the position of the X may be given as Washington 314B 2.5-3.6. Note that the horizontal distance is always given first, and that the horizontal distance may be east or west, depending on the quadrant (A,B,C, or D) of the grid. Similarly, the vertical distance is always last, and may be north or south from the 15° quad corner. The reason for this seemingly bizarre choice of reference is that most gridded maps have lines only at 15" intervals, and it is difficult to measure distances from the center of a grid's side, or worse, the center of a grid, when these are not marked accurately in advance. Specific instructions for the assignment of grid numbers are given in Attachment 10 to the CAP Emergency Services Manual (CAPM 50-15).



8.2 COMPASSES

8.2.0 General

A compass is a device used to determine direction. There are many types of compasses, but the only type of compass to be considered here is the <u>magnetic compass</u>. A magnetic compass has two primary parts: (1) a magnetic needle, and (2) a suspension of some sort, to allow the needle to turn freely. A simple and workable compass could consist simply of a magnetized needle suspended on the surface of a cup of water. Many additional features may be added, depending on the purpose of the compass.

The earth has a magnetic field, with north and south poles, as does any magnet. The north magnetic pole, however, is not at the same location as the "true" rota-

tional north pole; magnetic north is located in northern Canada. The magnetic poles are the origins of magnetic "lines of force" which extend from one pole to the other. A compass needle will line up along these lines. The direction of the lines is seldom that of the north-south on a map. The displacement of magnetic and "true" poles contributes to this, as do local effects such a large iron ore bodies. One may measure the angle between these lines and the "true" north-south direction; this is the magnetic declination (see figure 8-5). In Virginia, this declination is approximately $\frac{1}{52}$ west. (Each map gives a declination for that particular map.) The declination may be affected by ferromagnetic materials held near the compass.



FIGURE 8-5: Magnetic Declination

8.2.1 ORIENTEERING COMPASSES

Orienteering type compasses are well suited for the land navigation tasks required of GSAR personnel. An orienteering compass (see figure 8-6) has three major parts: (1) a magnetic needle on a bearing, (2) a central transparent needle housing with parallel lines on it, and degrees marked around the edge, and (3) a rectangular transparent base with a direction of travel arrow on it. There are three arrows on this type of compass: (1) the magnetic needle, (2) an arrow parallel to the lines in the needle housing, and (3) the direction of travel arrow on the rectangular base.

8.2.2 LENSATIC COMPASSES

The lensatic compass is widely used by the military, and may be used for orienteering and land navigation in general; however, the orienteering type is easier to use for most land navigation tasks. The lensatic compass (see figure 8-7) has the following main parts: (1) a magnetic needle, which is actually a disc with degrees marked on it, (2) a compass housing in two parts, the top of which has a hairline, and provides a straight edge parallel to the hairline, and (3) a moveable luminous

line. Thus, as with the orienteering compass, there are three arrows: (1) the magnetic needle, (2) the compass housing hairline, and (3) the moveable luminous line. A lensatic compass may be used in a manner similar to that of an orienteering compass; specific instructions are given in subsequent sections. However, some lensatic compasses do not have a straightedge along the side of the case, which makes their use for navigation (as explained herein) extremely difficult.



FIGURE 8-6: The Orienteering Compass



FIGURE 8-7: The Lensatic Compass

8.3 ORIENTEERING

8.3.0 General

Orienteering is an outdoor sport, originally from Scandinavia, which has gained a large following in the U.S. It involves a timed map and compass course, which requires of contestants good physical condition, map reading and compass skills, and the ability to make optimum route choices. Orienteering offers an opportunity to practice the majority of land navigation skills required for GSAR tasks. In addition, the concepts and techniques developed by and for orienteering are useful in almost any kind of land navigation problem.

The U.S. military services use orienteering as a vehicle for teaching land navigation skills, and the Army and Marine Corps orienteering teams are among the world's best. Much of the material in this section is adapted from military orienteering teaching materials.

The simplest type of orienteering course is a point-to-point course, as illustrated in figure 8-8. Contestants copy points from a master map onto their own, and are to go to each point in the order given. At each point, the contestant will find





Course

a marker, usually with a special paper punch, and is expected to document finding the marker by punching his ticket. The person completing the course (i.e. showing up at the end with a ticket with punchmarks for all markers) in the least time is the winner. There are many other types of orienteering courses, and the interested reader is referred to Kjellstrom's book Be Expert with Map and Compass for a discussion of them.

8.3.1 Orienteering Concepts

The concepts discussed in this subsection are central to the sport of orienteering, and will be of use in any type of land navigation task. Since some concepts are difficult to explain in prose, the reader is urged to make use of the illustrations in figure 8-9. Numbers refer to examples shown in figure 8-9.

Bearing. Also known as an azimuth, a <u>bearing</u> is simply a direction specified from true north (a true bearing) or from magnetic north (a magnetic bearing). For example, a true bearing of 90° is due East.

Northing Lines. (1) Many maps designed primarily for orienteering are often published with magnetic north-south grid lines across them. These lines, put there to simplify obtaining magnetic bearings from the map, are called <u>northing lines</u>.

<u>Catching Features</u>. (2,3) The bigger an object is, the easier it is to find. This principle applies to orienteering as well. Rather than trying to navigate a compass course directly to a small target, it is often easier to navigate first to a large linear <u>catching feature</u>, then to navigate further to the target.

In orienteering, it is customary to divide navigation into different types, based on the difficulty involved. The first stage of navigation from one point to another is known as rough orienteering or the "green segment", where often the only route description would be a rough direction, such as "east". Once the selected catching feature is reached, standard orienteering or the "green segment" is used. Often this may consist of nothing more than following along a catching feature such as a trail or stream for a while. Such catching features that lie roughly parallel to the intended route of travel are called "handrails". Sometimes, a catching feature on the far side of a target is selected, to "catch" oneself if the target is missed. Also, it may be easier to go to a catching feature on the far side of the target, then navigate back to the target, rather than to aim directly for the target.

<u>Attack Points</u>. (4,5) The final part of navigation to a target, known as precision orienteering or the "red segment", involves careful use of compass and pacing. Since following a compass course precisely is difficult, and errors increase with increasing distance, the distance to be precisely navigated must be minimized by the use of catching features. When selecting catching features, and planning a route in general, you must look for <u>attack points</u>, points that may be precisely located both on the map and in the field. In general, the attack point closest to the target should be chosen, even if it is on the far side of the target, in order to minimize the distance of the "red segment".

Aiming Off. (6) A "T" intersection of one sort or another is occasionally selected as an intermediate target or attack point. If one is approaching the intersection from "above" the T, one will probably come out somewhere along the "top" of the T, with no clue as to whether the intersection is to the left or right. To avoid this problem, it is simple to <u>aim off</u> to one side or the other. In this way, the way to turn once one hits the top of the T is known. For example, if one were deliberately to steer a course 5° to the left (5° less than the bearing directly to the intersection), one would immediately turn right upon reaching the top of the T, and soon reach the intersection.

<u>Collecting Features</u>. It is not advisable to strike off on foot along a bearing towards a target, without having some idea of the distance involved. It is possible to be on the right track to reach the target, only to turn back too soon for fear of having overshot it. To avoid this type of problem, one must maintain a constant knowledge of one's position. There are two primary methods for doing so, pacing,



FIGURE 8-9: Orienteering Concepts

Small numbers are target point numbers; large numbers in parentheses are keys to explanations in the text. which is discussed in a subsequent section, and <u>collecting features</u>, which will now be described. Collecting features refers to the act of preparing a mental list of landmarks along a planned route. As each is passed, it is checked off the mental list. Thus, a close check is kept on one's position. If a major feature is apparently out of place on the list, or missing, it is time to stop and reassess one's position and route.

Backwards Route Planning. (7,8) In general, one should plan a route from target to starting point, rather than from starting point to target. This is due to the ease of selecting good attack points when planning "backwards". Examples of four routes, two planned forwards and two planned backwards, are given in figure 8-9 (7,8). The dotted lines (from station 3 to 4 and 6 to 7) represent the forwards-planned routes which contain longer red segments (precision navigation) to the target.

8.3.2 Route Selection

Proficiency in the art of route selection is necessary for GSAR personnel. The ability to evaluate routes for speed, distance, and difficulty is not only required for GSAR navigation tasks, but is an important survival skill as well. Route selection skills may easily mean the difference between a half-hour hike and a half-day bushwhack.

A good route between two points will usually minimize the use of the compass. An experienced orienteerer will run a basic level orienteering course with little or no use of the compass. (However, even the most experienced GSAR team member will find occasions requiring the use of a compass.) One of the major considerations in route selection is that of <u>elevation gain</u>. As a general rule of thumb, twenty-five feet climbed is the equivalent of 100 meters (approximately 300 feet) of level foot travel, in terms of energy expended. Another consideration is that of <u>vegetation</u>. If one is confronted with a patch of brush, a choice must be made between pushing on through the brush, or going around it. Although it is difficult to provide a quantitative expression for difficulty due to brush, the following table will provide a rough indication of travel times for two and one half miles of level foot travel:

path or road:	one hour
light vegetation:	two hours
open woods:	three hours
dense forest:	five hours
laurel/rhododendron:	ten hours.

Specific terrain features such as cliff bands, rivers, and marshes may influence difficulty and travel time.

Route selection is perhaps the one most important skill for GSAR land navigation, and is one of the most difficult to learn. One of the best methods to develop a facility for route selection is to participate often in orienteering meets. Many areas have orienteering clubs sponsoring regular meets; GSAR team members are encouraged to seek out these activities.

8.4 DETERMINING A BEARING

8.4.0 General

Given a starting point and a target on a map, one must select a route between the two, using the concepts porvided in the last two sections. Sometimes it will be necessary to plot and follow a direct bearing from an attack point to a target point or catching feature. This section will discuss how to arrive at a proper bearing between two points plotted on a map.

8.4.1 Map, Protractor, and Straightedge Method

One may derive a true bearing from a map with a protractor and straightedge, as follows: (this procedure is illustrated in figure 8-10)

- 1. Draw a line from attack point to target, and extend it until it meets a north-south line on the map (e.g. the map edge).
- 2. Using the protractor, measure the angle formed between map north and the desired line of travel, measuring clockwise. Take care not to measure the angle from north to the line of travel <u>backwards</u> from target to attack point.
- 3. This angle is a true bearing from attack point to target; a declination correction must be added or subtracted to obtain a magnetic bearing for use in the field.



1. Using straightedge, extend line connecting starting point (attack point) and target to a map north-south line.

2. Using protractor, measure angle from map north to intended travel direction (two examples shown).

3. The angle measured is a true bearing; add or subtract the proper magnetic declination correction to obtain a magnetic bearing for use in the field with a magnetic compass.

FIGURE 8-10: Protractor/ Straightedge Method for Determining Bearings

8.4.2 Magnetic Declination

Since true bearings and magnetic bearings are not equivalent, except in a very few locations, one must be able to convert from true bearings (as from a topographic map) to magnetic bearings (as taken or used in the field with a magnetic compass) and vice versa.

Declination is the difference between true north and magnetic north, or for that matter the difference between any two corresponding true and magnetic bearings (a point worth several minutes of thought, if it is not immediately clear). Declination is specified as being east or west. West declination, as in Virginia, means that a magnetic needle will point slightly to the west of true north. In terms of degrees, (where $0^\circ = 360^\circ = \text{north}$, $90^\circ = \text{east}$, $180^\circ = \text{south}$, $270^\circ = \text{west}$), true north is a few degrees more (i.e. clockwise) than magnetic north, and magnetic north is of course a few degrees less (i.e. counterclockwise) than true north. Similarly, magnetic east is a few degrees less than true east, and true west is a few degrees more than magnetic west. Thus when converting from a magnetic bearing (e.g. one obtained from triangulation in the field) to a true one (e.g. to be plotted on a map), one must <u>subtract</u> the declination. Similarly, when converting from a true bearing to a magnetic one (as when taking a bearing off a topographic map for use in the field), one must <u>add</u> the declination.

A final example will be given to give a better intuitive understanding of declination. Let us say that we are considering a bearing from point A to point B, as shown in figure 8-11. We may then assign to this actual line of travel a true bearing, which is the number of degrees from true north to the line of travel, measured clockwise from true north. Similarly, we may assign to the line of travel a magnetic bearing, which is the number of degrees from magnetic north, again measured in a clockwise direction. We see that the magnetic bearing is a larger angle than the true bearing, and since this is so, it is intuitively obvious that we must <u>add</u> declination to correct from true to magnetic bearings, and <u>subtract</u> the declination to go from magnetic to true bearings. Rather than to continue attempting to explain declination adjustment in this section, it is recommended that readers obtain a map and compass and practice with them to increase their understanding of declination.



FIGURE 8-11: Declination correction

8.4.3 Map and Compass Method

Since protractor and straightedge are not always available in the field, an alternate method using map and compass is described below. Although the description assumes the use of an orienteering compass, the procedure may be used with lensatic or other compasses with some minor changes.

1. Orient the map precisely to true north. (An oriented map is one that is turned so that map and actual directions coincide; that is, the top of the map points due north.) This may be done by inspection of the surrounding terrain, or by use of the compass as follows:



FIGURE 8-12: Map and compass method for determining bearings (continues on next page)



8-17

(figure 8-12 continued)

- a. Place the compass on the map with the edge of the compass base along the edge of the map and the direction of travel arrow pointing to map north (see figure 8-12a).
- b. Turn the needle housing to the indicated magnetic declination: 0° plus the declination for west declination, 360° minus the declination for east declination (see figure 8-12b).
- c. Turn the map and compass as a unit until the magnetic needle is centered properly in the needle housing arrow (see figure 8-12c).

2. Without moving the map, place the side of the compass base along the line from attack point to target with the direction of travel arrow pointing towards the target (see figure 8-12d).

3. Turn the needle housing until the needle housing arrow and the magnetic needle coincide. A magnetic bearing is now shown by the compass (see figure 8-12e).

It is also possible to orient the map to magnetic north initially, then to correct later for magnetic declination. Also, if one were to turn the needle housing arrow to map (true) north instead of magnetic north in step three, above, a <u>true</u> bearing would result.

Using the Lensatic Compass

1. Orient the map precisely to true north:

- a. Place edge of opened compass along the map edge, with hairline pointing to map north.
- b. Turn map and compass as a unit until the compass reads the specified magnetic declination (e.g. reads 6° for 6° west declination).

2. Place the edge of the opened compass along the line from attack point to target, with the hairline pointing in the direction of intended travel (towards target).

3. Move the luminous line over the north arrow.

4. Read off the magnetic bearing under the hairline.

8.5 FOLLOWING A BEARING

Once the compass is set for a given magnetic bearing, <u>commit the bearing to</u> <u>memory</u>, as it is possible to inadvertantly change the compass setting, especially when traveling through brush or rough terrain. For this same reason, one should check the compass setting frequently.

The compass is held in the hand (palm up), directly in front of the body, at elbow height. One then rotates, keeping the compass in front, until the needle is lined up in the needle housing arrow. (For a lensatic compass, rotate until "north" on the needle is under the luminous adjustable line.) To follow this bearing, one merely travels in the direction one is facing.

Staying on a bearing may be difficult. A small error in the bearing will result in an error at the target, with the magnitude of the error increasing as the distance the bearing is followed increases (see figure 8-13a). Even if there is no error in the bearing, continued "drift" may result in error, even though one's course is corrected back to the proper azimuth at regular intervals (see figure 8-13b).



FIGURE 8-13: Errors in following a bearing

There are several methods for following a bearing accurately. Perhaps the simplest is to choose an intermediate "target" (e.g. a tree), directly on the bearing. Once this is reached, the compass is used to select another target.

A refinement on this is to sight past the first target and immediately pick out a second target in line with the first. As the first target is reached, a third is chosen, and so on. This may seem more complex and time consuming than the method described above, but is actually much quicker, as fewer compass readings are required.

When traveling in a team, and when extreme accuracy is required, it is possible to send a member on ahead. Verbal instructions to this member will suffice to keep him or her on the proper heading. With practice, this may be done with a minimum of delay and very accurately.

Sometimes a detour may be necessary when following a bearing. If a target can be sighted on the other side, there is little problem. However, if such is not the case, techniques known as "triangulation around an obstacle" (distinct from triangulation as discussed in 8.7.3) and "boxing" may be employed. <u>Triangulation</u> refers to the interposition of a triangle into the route bearing (see figure 8-14a). As the obstacle is reached along one's bearing Θ , a new bearing of Θ plus or minus Φ is set (in figure 8-14a it is Θ minus Φ); Φ is picked so as to "triangulate" around the obstacle with a minimum of extra walking. A distance, <u>x</u>, is traveled along the new bearing, then a third bearing of Θ minus or plus Φ is set along this third bearing, bringing one back into line with the original bearing Θ . If the angle Φ is chosen to be 45° (which is often possible) then the equivalent distance along the bearing Θ (AC in figure 8-13a) is equal to about 1.4x. An example is given in figure 8-13b.

Boxing is somewhat longer in terms of distance, but simpler in terms of calculations. As the obstacle is reached along bearing θ , a new bearing of θ plus or minus 90° (θ minus 90° in figure 8-14c) is traveled a distance y until one is clear of the obstacle. The bearing θ is again followed until past the obstacle, then the bearing θ minus or plus 90° (θ plus 90° in figure 8-14c) is followed the same distance y back to the original bearing.





FIGURE 8-14: Navigating a bearing around obstacles



8.6 DETERMINING DISTANCE

There are two primary methods for estimating the distance one has traveled. The first is by the use of collecting features as described in a previous section (8.3.1). Often it is necessary to estimate distance without the use of collecting features, or in between such features. This is done by counting the number of <u>paces</u> taken, a pace being counted each time the left foot touches ground. Every person has a unique stride, and strides vary under different conditions of terrain, brush, and steepness, and when running, trotting, or walking. Every GSAR team member should learn his pace length under various conditions. The following chart may be of use for new GSAR personnel:

	Number of	paces in 100 met	ers (for a fresh
	person, i	person, in daylight, on level	
	Small (<	5 ' 8") Medium	Tall $(> 6^{\circ})$
Road/Trail	42	40	37
Light Vegetation	45	43	40
Open Forest	50	46	43
Dense Forest	55	50	46

8.7 DETERMINING POSITION

8.7.0 General

Determining a position in the field may be difficult and trying to even the most experienced GSAR team member. Keeping track of position constantly is simple with the use of a map and collecting features. A useful hint is to hold the map in one hand, with a thumb on the map marking the present position. As each collecting feature is passed, the thumb may be moved up. Another good idea is to count paces regularly, so the distance back to the last "collecting" feature is known. Some orienteering compasses even have a built-in register for keeping track of paces.

Mission tasks will occasionally require the GSAR team member to be able to determine position with little information to guide him, and the ability to determine position is an important survival skill.

8.7.1 Position by Inspection

Sometimes it will be possible to determine one's position by simply orienting the map and inspecting the surrounding terrain. Since this method may produce several map locations possibly corresponding to one's actual position, the following procedure is suggested:

- 1. List the map locations possibly corresponding to the team's location.
- 2. Determine a route for the team (e.g. proceed north, or go downstream) which will provide different clues if followed from each of the possible locations on the map.
- 3. Once one of these clues is located, the team's position is known.

8.7.2 Position by Resection

If one is along a known linear feature (road, stream, trail, ridgeline) and a prominent landmark is sighted, one's position may be determined. The magnetic bearing to the landmark is determined and recorded. This is done as follows:

- 1. Sight (point) the compass at the landmark.
- 2. Turn the needle housing until the needle housing arrow and the magnetic needle coincide.
- 3. Read the magnetic bearing under the direction of travel arrow (leave this setting on the compass).

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LANDMARK 1 TEAM'S POSITION LANDMARK 2

(map oriented to true north)

FIGURE 8-15:

Resection

The map is now oriented to true north as described in section 8.4. The edge of the compass may be placed so as to cross through the landmark on the map (see figure 8-15a). The compass base edge is then pivoted around the landmark until the magnetic arrow and needle housing arrow coincide (see figure 8-15b). The intersection of the compass edge line with the linear feature then marks one's position.

If the team is not on a linear feature it is still possible to use bearings from two or more landmarks to determine the team's position, as shown in figure 8-15c. Lines are plotted from each landmark as described above, with the intersection of the bearing lines marking the team's position. This process is known as resection.

A

C

BEARING

LANDMARK

LANDMARK

8.7.3 Position by Triangulation

It may occasionally be necessary to specify the location of a position distant from one's own, for instance a possible crash site on a mountainside. The process of <u>triangulation</u> used for this purpose is essentially the reverse of resection. The team takes magnetic bearings on the possible crash site from two or more known locations. These bearings are plotted as shown in figure 8-16 and their intersection marks the possible crash site location. It is also possible to use bearings from an ELT locator and to triangulate to derive an estimated ELT position. When plotting bearings, pivot the compass base edge around one's location (A, B, or C in figure 8-16).

8.7.4 Making Positions Easily Found

One of the tasks of the first team to a crash site or to a lost person is to guide in additional teams. Although the site location may be reported to the incoming teams via radio, this is not always sufficient to avoid delays in the team's arrival.

It is possible to leave a trail marked by plastic surveyor's tape to the site, but often this is not feasible. An alternative is to provide a bearing from an attack point which is

easily located. In order to make the site a larger target, surveyor's tape markers may be placed to either side of the site, as shown in figure 8-17a. Use of single flags to the "left" of the site and double flags to the "right" of the site will also aid teams in finding the site more quickly. If teams may arrive from multiple directions, a three-arm array may be set out, as in figure 8-17b.



A. Team approaching from known direction



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FIGURE 8-16: Triangulation (bearings from three team positions to target plotted as shown in fig. 8-15)

B. Team(s) approaching from unknown or multiple directions

FIGURE 8-17: Site marking

8.8 EMERGENCY DETERMINATION OF DIRECTION

8.8.0 General

The possibility of becoming stranded without a compass may be small. Even so, this small chance is enough to make knowledge of emergency direction determining methods worthwhile for GSAR personnel. This section will provide brief descriptions of four possible methods.

8.8.1 Sun Method

Virginia, which is at a latitude of approximately 38° , is north of the Tropic of Cancer and south of the Arctic Circle. Therefore, the sun rises in the east, describes an arc to its noon position in the south, and continues down to set in the west. The sun's noon height above the southern horizon varies from 75° at midsummer noon to 52° at midwinter noon. Thus a glance at the sun's position and a knowledge of the season and time of day may provide a rough indication of direction.

8.8.2 Sun and Stick Method

If accuracy is important, and time is available, the relative motion of the sun across the sky may provide an accurate direction indication by the following method:

- 1. Place a tall stick upright in the ground.
- 2. Mark the tip of the stick's shadow at several intervals (timing is not of major importance).
- 3. Draw a perpendicular from the stick's base to the line drawn in step two. The "T" thus formed has its arms pointing east and west, and the base pointing south, as shown in figure 8-18. (When used south of the equator, the direction indicated by the base of the "T" is north, not south.) This method has limited usefulness in Virginia survival situations, since this kind of accuracy is usually not necessary--the sun method will do just as well and take less time.



FIGURE 8-18: Stick and sun method of determining direction

8.8.3 Sun and Watch Method

This method is not as accurate as the sun and stick method, but is much quicker. It requires a watch or clock that is running properly. If the hour hand of the watch is pointed towards the sun, the midway between 12 on the watch and the hour hand points south (see figure 8-19a). If after 6 pm or before 6 am, the <u>larger</u> angle between 12 and the hour hand should be used. Error is reduced if the watch is held horizontally tangent to the earth's surface at the equator (figure 8-19b). At 38° north, the watch would thus be tilted down 38° from horizontal towards the south. This method works south of the equator, but the indicated direction is north.



FIGURE 8-19: Watch and sun method of determining direction



a. The Big Dipper indicates the North Star

FIGURE 8-20: The use of the stars to determine direction



b. The right-hand star in the "belt" of the constellation Orion always rises directly in the east and sets directly in the west

8.8.4 Star Observation Method

In the northern hemisphere Polaris (the North Star) provides a quick reference to north. The North Star is located in the night sky as shown in figure 8-20a. It is always within about 1° of true north. The striking constellation Orion (The Hunter) spans the celestial equator, with the right star in the "belt" being precisely on the equator. This star always rises precisely in the east and sets precisely in the west. Orion is illustrated in figure 8-20b.

8.9 REFERENCES

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