Chapter

5

5. Scanning Techniques and Sighting Characteristics

OBJECTIVES:

1. Define "scanning" and "fixation,' and describe how aircraft motion effects scanning.
2. Discuss central and peripheral vision, and describe where your focal point is when you are relaxed.
3. Discuss fixation points and lines of scan; define "scanning range."
4. Describe the diagonal and vertical scanning patterns.
5. Discuss how atmospheric and lighting conditions affect scanning.
6. Discuss common visual clues and wreckage patterns.
7. Discuss tips on reducing fatigue while scanning.
8. Describe how to give directions to the pilot while in flight.

5.1 Scanning

Scanning is the process of investigating, examining, or checking by systematic search. In search and rescue operations, the scanner or observer visually searches the search area for distress signals or accident indications by using a systematic eye movement pattern. The observer manages all scanning aboard the search aircraft by assigning an area of responsibility to each individual scanner (e.g., in a C172 the observer will scan out the right side and the scanner will scan out the left side of the aircraft). When the search aircraft nears the designated search area, the mission observer must ensure that all crewmembers are aware of their respective areas of responsibility and ready to begin the visual search.

The most commonly used eye movement pattern involves moving the eyes, and thus the field of view, laterally or vertically while pausing every three to four degrees. This pause is known as a *fixation*. This pattern should be used at a rate that covers about 10 degrees per second.

Search aircraft motion causes the field of view to continuously change, making this scanning technique most appropriate for occupants in the front seats of small aircraft. At side windows of larger aircraft, eye movements are directed away from the aircraft to the effective visibility range and then back to a point close to the aircraft's ground track. The scanner should maintain this routine to systematically cover an assigned sector. The mission observer determines when rest periods are taken, or directs other fatigue-reducing measures. Scanning patterns should be practiced often in order to maintain or increase scanning proficiency.

Your job is to concentrate on scanning for the objective within the search area. Anyone can "look," but scanning is more than just looking. Scanning is the skill of seeing by looking in a methodical way, and there are certain techniques that can help you develop this skill. In this section, we will present these techniques. But more than knowing scanning techniques is required. You need practice at using the techniques so that your ability to scan becomes second nature.

5.2 Vision

The primary tools of the scanner are your eyes. Although an eye is a marvelous device, it has some limitation even if it is in perfect physical condition. There also is the problem of interpreting correctly what the eyes convey to the brain.

When a person with normal eyes looks straight ahead at a fixed point, much more than just the point is seen. The brain actively senses and is aware of everything from the point outward to form a circle of 10 degrees (visual acuity outside of this cone of vision is only ten percent of that inside the cone). This is central vision, produced by special cells in the fovea portion of the eye's retina. Whatever is outside the central vision circle also is "picked up" by the eyes and conveyed to the brain, but it is not perceived clearly. This larger area is called peripheral vision; cells less sensitive than those in the fovea produce it. For example, an object that is visible one mile away using central vision would only be visible 500 feet away using peripheral vision. However, objects within the peripheral vision area can be recognized if mental attention is directed to them. Figure 5-1 shows the span of human vision.

Span of Vision

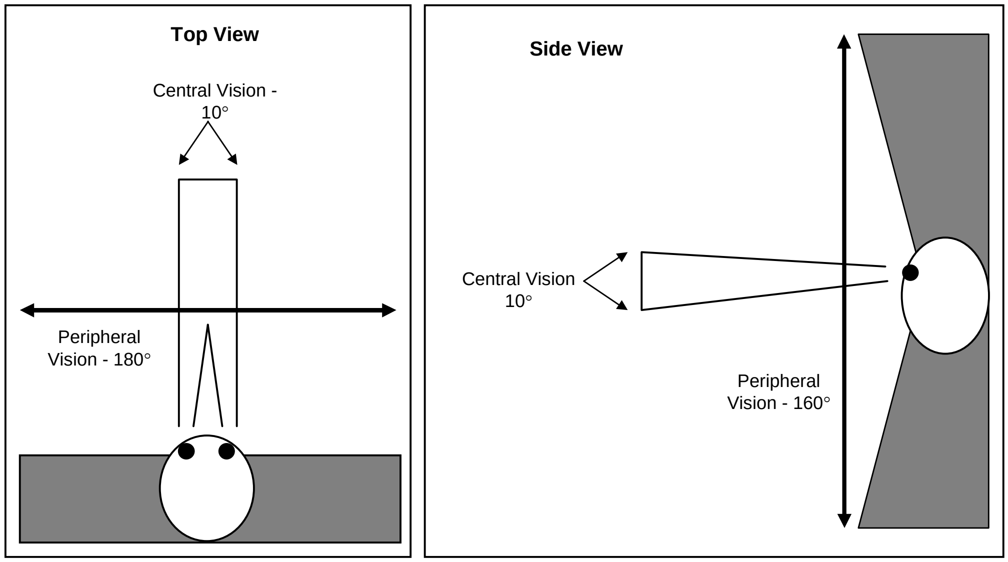

Figure 5-1

Note that peripheral vision is very important at night, and is also important in picking up structures such as towers.

The fixation area is the area in which "concentrated" looking takes place. If the search objective happens to come within this fixation area, you probably will recognize it. It is possible to miss a search object even if it is in the fixation area because there are other factors such as fatigue and weather that also influence whether the objective will be recognized (covered later).

For central vision to be effective, the eye must be focused properly. This focusing process takes place each time the eyes, or head and eyes, are moved. When you are not actively focusing for about a minute while looking outside the aircraft, your focal point will shrink to a point about 30 feet out. Thus, daydreaming or thinking about other things while you are supposed to be looking for the target will guarantee you will not see the target even if your eyes are pointed right at it!

Let's introduce a reason for scanners to move their heads while scanning. Good central vision requires that the eyes be directed straight to the front. Side looking, in other words, can reduce the effectiveness of central vision. Why? Very simply, the nose gets in the way. Take a moment and focus on an object well to your right, but keep your head straight. Now close your right eye. Notice that your central vision is cut in half, although you did not realize it.

5.3 Fixation Points and Line of Scan

When you wish to scan a large area, your eyes must move from one point to another, *stopping one or two seconds at each point* long enough to focus clearly (a continuous scan tends to blur your vision). Each of these points is a "fixation point." When the fixation points are close enough together, the central vision areas will touch or overlap slightly. Focusing on these points enables your central vision to more clearly detect objects, and increases your peripheral vision's ability to detect contrasting objects. Spacing of fixation points should be 3 or 4 degrees apart to ensure the coverage will be complete (Figure 5-2). Consciously moving the fixation points along an imaginary straight line produces a band of effective "seeing."

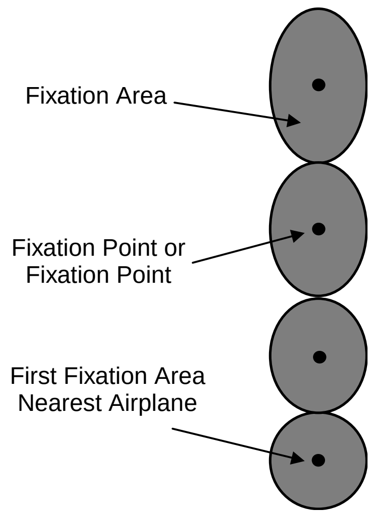

Figure 5-2

The fist held at arm's length approximates the area of central vision, and you can use this fact to help you practice your scanning technique (Figure 5-3). Extend your arm at eye level and picture that you are looking through the back of your fist. Look "through" your fist and focus your eyes on the center of the area that would be covered if you were looking at instead of through your fist. Now move your fist to the right to a position next to and touching the previous area (refer to Figure 5-4). Again, look "through" your fist and focus on the center of the fist-sized area on the other side of your fist. If you continue to move your fist along a line, stopping and focusing your eyes on the center of each adjacent fist-sized area, you will have seen effectively all of the objects along and near that line. You will have "scanned" the line.

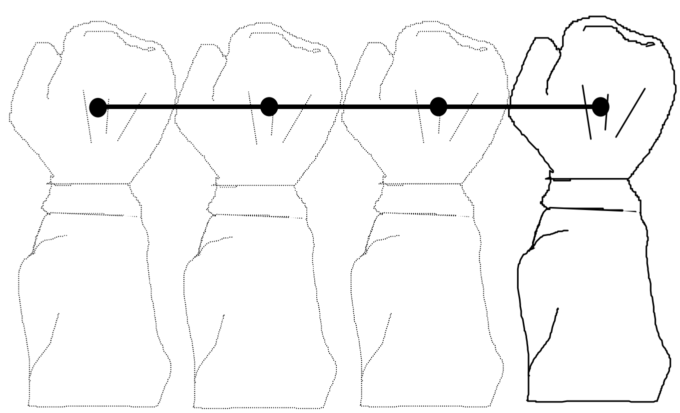

Figure 5-3

Repeat this process but establish starting and stopping points for the line of scan. Pick out an object on the left as the starting point and an object on the right as the stopping point. Start with the object on the left. Extend your arm and look through your fist at that object. As practiced before, continue moving your fist to the next position along an imaginary line between the objects. Remember to stop briefly and focus your eyes. When your eyes reach the object on the right, you will have scanned the distance between the objects.

Follow the same procedure but scan between the two objects without using your fist as a guide. Move your head and eyes to each fixation point as before. Pause just long enough to focus clearly (about 1/3 second). When you reach the object on the right you will have *scanned* the line or area between the two objects and you will have scanned the line in a professional manner.

5.3.1 Fixation area

The goal of scanning techniques is to thoroughly cover an assigned search area. Reaching this goal on a single overflight is not possible for a number of reasons. First, the eye's fixation area is a circle and the search area surface (ground) is flat. Coverage of a flat surface with circles requires much overlapping of the circles. This overlapping is not possible on a search mission because of the aircraft's motion (Figure 5-4). Also, the surface area covered by the eye's fixation area is less for the area near the airplane and increases with distance from the airplane. The net result is relatively large gaps in coverage near the airplane and some overlap as distance from the airplane increases. Figure 5-2 is not to scale, but it gives a good idea of how these gaps and overlaps occur. Notice how the surface area covered begins as a relatively small circle near the airplane and takes an increasingly larger and more elliptical shape farther out. Also, Figure 5-3 shows how the forward motion of the aircraft may affect this coverage pattern. You should be aware of this affect and not allow it to cause major gaps in your scanning pattern coverage.

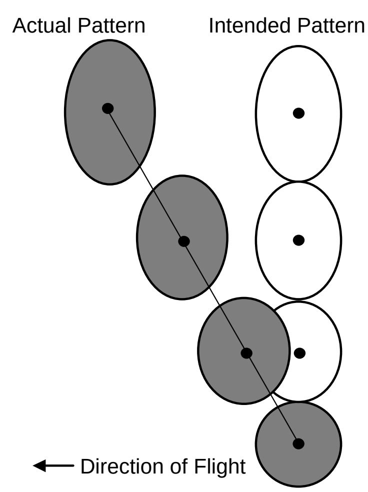

Figure 5-4

Angular displacement is the angle formed from a point almost beneath the airplane outward to the scanning range, or beyond. By this definition, the horizon would be at 90 degrees displacement. Although the fixation area may be a constant 10-degree diameter circle, the effectiveness of sighting the objective decreases with an increase in this angular displacement. Said another way, your ability to see detail will be excellent at a point near the aircraft, but will decrease as the angular displacement increases. At the scanning range, at which the angular displacement may be as much as 45 degrees, the resolution of detail area probably will have shrunk to a 4-degree diameter circle.

This is why having scanners looking out both sides of the aircraft is optimal. With track spacing (explained later) proper for the given search visibility, each scanner will look at roughly the same area (i.e., double coverage).

5.3.2 Field of scan

The area that you will search with your eyes in lines of scan is called the field of scan. The upper limit of this field is the line that forms the scanning range. The lower limit is the lower edge of the aircraft window, while the aft (back) limit is usually established by the vertical edge of the aircraft window. The forward (front) limit for a field of scan will vary. It might be established by a part of the airplane (such as a wing strut). Or, when two scanners are working from the same side of the airplane it might be limited by an agreed-upon point dividing the field of scan.

5.3.3 Scanning Range

We are using the term “scanning range” to describe the distance from a moving aircraft to an imaginary line parallel to the aircraft’s ground track (track over the ground.) This line is the maximum range at which a scanner is considered to have a good chance at sighting the search objective.

Scanning range sometimes may be confused with search visibility, which is that distance at which an object on the ground, usually an automobile, can be seen and recognized from a particular height. Aircraft debris may not be as large as an automobile and may not be immediately recognizable as aircraft debris, particularly when the aircraft is flying at 100 mph. Therefore, scanning range may be less than but never greater than the search visibility (in searches, we rarely credit a search visibility of greater than three or four nautical miles).

From an altitude of 500' AGL and a scanning angle of 45**º**, the ratio of altitude to scanning range is one-to-one, so scanning range is only 500 feet; at 1000' AGL and 45**º**, scanning range is 1000 feet. To achieve scanning ranges applicable for typical search altitudes, the scanning angle (angular displacement *below the horizon*) typically would be 10**º** (farther limit) and 20**º** (closer limit) for scanning range at each altitude.

The following chart depicts the scanning ranges associated with various combinations of scanning altitudes and angles. From this, scanning ranges of one-half mile or greater would require a compromise in either higher altitudes or low depression angles. For lower scanning angles, the fixation area within the scanning cone would be extremely elongated (and much smaller), whereas for higher altitudes the size of objects on the ground would be smaller and thus harder to detect.

Altitude (AGL)	Scanning Range (feet)	Scanning Range (miles)	Scanning Angle (º)
500'	866	0.164	30
	1374	0.260	20
	2836	0.537	10
1000'	1732	0.328	30
	2747	0.520	20
	5671	1.074	10
1500'	2598	0.492	30
	4121	0.781	20
	8507	1.611	10

** Angular displacement measured from the horizon

Concerning scanning technique, with this chart representing the relationship of altitude and angle, use of depression angle would seen to provide the most practical approach for estimating scanning range. Thus, for a deflection angle of 70**º**, the depression angle is 20**º** (e.g., about two “fists” below the natural horizon). To provide a reference mark of the scanning range for the scanner in the rear seat, a piece of masking tape could be placed on the front of the window frame equivalent to the depression angle used to estimate the scanning range. A similar reference mark could be placed on the bottom of the window for the scanner in the front sear.

If your pilot states that the search altitude will be 1,000' AGL, you can expect a scanning range of between ½ and 1 mile. If you drop down to 500' AGL to investigate a potential sighting, you can expect your scanning range to be ¼ to ½ mile. There are many variables that affect both the effective scanning range and your probability of detecting the search objective; these are discussed later.

5.4 Scanning patterns

To cover the field of scan adequately requires that a set pattern of scan lines be used. Research into scanning techniques has shown that there are two basic patterns that provide the best coverage. These are called the *diagonal pattern* and the *vertical pattern.*

Figure 5-5 illustrates the way the diagonal pattern is used when sitting in the right rear seat of a small airplane. This line is followed from left to right as in reading. The first fixation point is slightly forward of the aircraft's position. Subsequent fixation points generally follow the line as indicated in the figure.

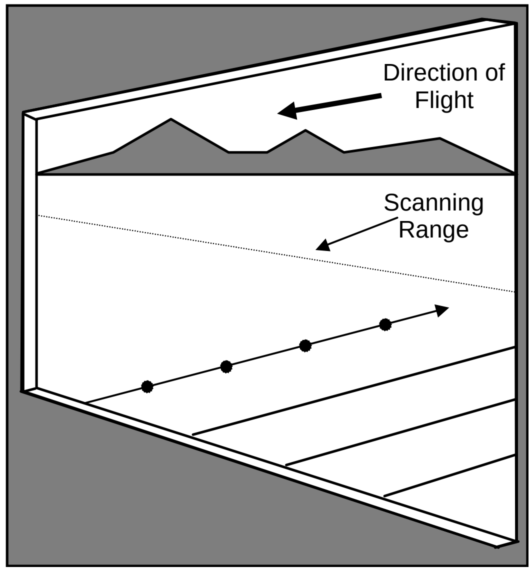

Figure 5-5

The next scan line should be parallel to the first, and so on. Each succeeding scan line is started as quickly as possible after completing the previous one. Remember, the duration of each fixation point along a scan line is about 1/3 second. How long it takes to complete one scan line depends on the distance at which the scanning range has been established. Also, the time required to begin a new scan line has a significant influence on how well the area nearest the airplane is scanned. In other words, more time between starting scan lines means more space between fixation points near the airplane. Note that this is why search speed control is so important; experience has shown that speeds of 80-100 knots are best, depending upon search objectives and conditions.

When the diagonal scanning pattern is used from the *left* rear window (Figure 5-6), the direction of scan lines still is from left to right, but each line starts at the scanning range and proceeds toward the airplane. Each scan line on this side terminates at the window's lower edge.

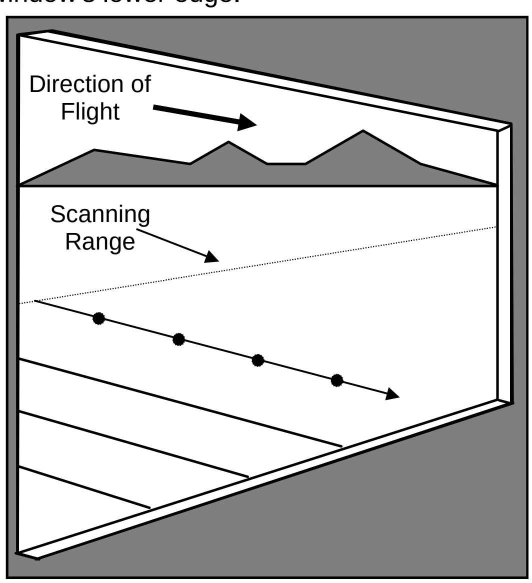

Figure 5-6

Figure 5-7 gives you an idea of the surface coverage obtained with a diagonal scanning pattern.

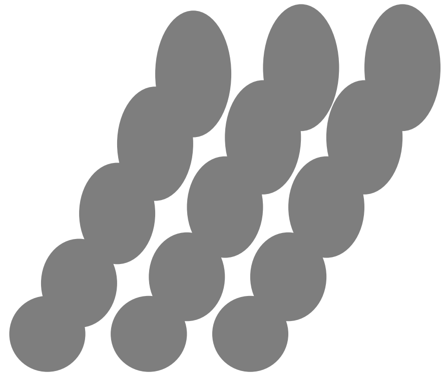

Figure 5-7

The second and somewhat less effective scanning pattern is illustrated in Figure 5-8. This pattern is vertical and is basically the same as the example shown in Figure 5-2. You should use this vertical pattern only from a rear-seat position, and the first fixation point should be as near to underneath the airplane as you can see. Subsequent fixation points for this first scan line should progress outward to the scanning range and back.

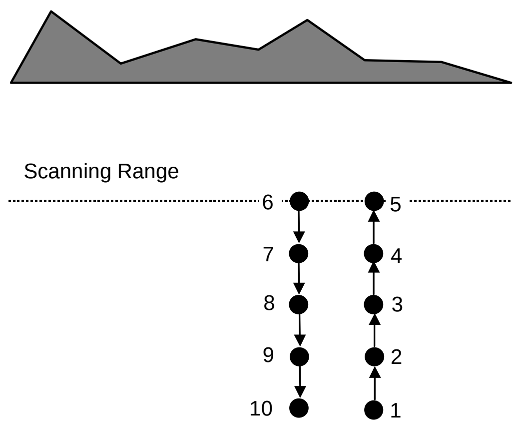

Figure 5-8

Figure 5-9 reveals the sawtooth shape this vertical pattern makes on the surface. Observe how much surface area near the airplane is not covered.

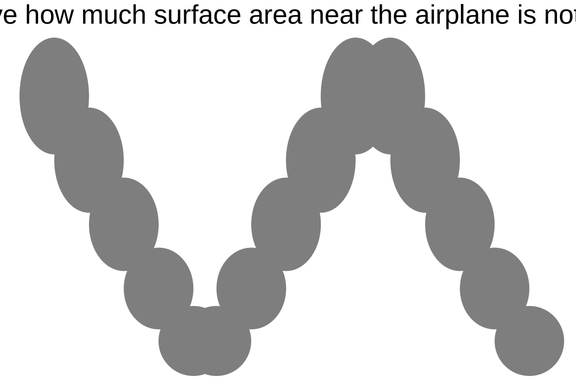

Figure 5-9

If there are two scanners on the same side of the airplane, it is good practice to combine the diagonal and vertical patterns. As agreed between scanners, one would use the diagonal pattern and the other the vertical pattern. However, the scanner using the vertical pattern *would not* scan to the scanning range. Some distance short of the scanning range would be selected as the vertical-pattern limit. This technique provides good coverage of the surface area near the search aircraft.

When flying in the right front seat of an airplane you will use the diagonal pattern. This is true because it is the only pattern that has a natural flow to it from this particular position. Because of the aircraft's structure, you probably will want to begin your scan line near the line of flight over the surface. This will be somewhat ahead of the airplane (not much). The angle of the scan line and its length will be determined by whatever structural part obstructs your vision. For example, you could use the window post on some aircraft as either a starting point or stopping point, depending on your judgment. If you are in the right front seat of a low-wing model, the wing will be the stopping point.

Scanners, especially those with considerable experience, may use a system or pattern that is different from the diagonal and vertical patterns discussed above. Many search objectives were found and many lives were saved long before there was an effort to analyze the scanning process and develop recommendations for its improvement.

5.5 Atmospheric and lighting conditions

During daylight there are many factors that can affect the scanner's ability to spot the search target. The following table shows the (approximate) distance at which the scanner can sight various objects under average visibility conditions; factors that can alter these distances are discussed below.

Object	**Distance**
Person in life jacket (open water or moderate seas)	1/2 mile
Person in small life raft (open water or moderate seas)	3/4 mile
Person in open meadow within wooded area	1/2 mile or less
Crash in wooded area	1/2 mile
Crash on desert or open plain	2 miles
Person on desert or open plain	1 mile or less
Vehicle in open area	2 miles or less

During darkness, scanners make fewer fixations in their search patterns than during daylight because victims in distress are likely to use lights, fires, or flares to signal rescuers. Contrast between signal light and surrounding darkness eliminates the need for scanners to concentrate on making numerous eye fixations. An attentive scanner or observer should be able to see a light, flare, or fire easily during night operations. Search aircraft interior lighting should be kept to the lowest possible level that still allows normal chart reading. This will help the eyes adjust to the darkness and reduce glare on windshield and window surfaces. Red or green lights are used when flying at night because that color has little or no affect on the low-light adaptation of the human eye. Regardless of light conditions, a scanner should always maintain a systematic scanning pattern with fixations every few seconds. Darkness merely lengthens the interval between fixations.

5.5.1 Atmospheric conditions

All aircrews hope for perfect visibility during a SAR mission. Seldom does this atmospheric condition exist. Most of the time the atmosphere (especially the lower atmosphere) contains significant amounts of water vapor, dust, pollen, and other particles. These items block vision according to their density. Of course, the farther we try to see the more particles there are and the more difficult it is to sight the objective.

The urgency of finding a downed aircraft may require flight under marginal conditions of visibility. An example here is flight through very light rain or drizzle. Another example is flight during the summertime when the air is not moving appreciably. It may become virtually saturated with pollutants.

5.5.2 Position of the sun

Flying “into the sun,” soon after it rises in the morning or before it sets in the afternoon, poses visibility problems. No doubt you have had this experience while driving or riding as a passenger in an automobile. Recall how difficult it is to distinguish colors and to detect smaller objects.

Research in search and rescue techniques has determined that the best time to fly search sorties is between mid-morning and mid-afternoon. This is when the sun is about 30 degrees or more above the horizon. When the sun is below this angle, it intensifies visibility problems.

As the sun climbs higher in the sky it helps to relieve visibility problems caused by the presence of particles in the atmosphere. The sun’s rays heat the ground and the atmosphere. This heat causes the lower atmosphere to expand. As the atmosphere expands the particles it contains are spread farther apart, decreasing their density within a given volume. Therefore, there are fewer particles between the surface and the scanner’s eyes and the effective scanning range is increased slightly.

5.5.3 Clouds and shadows

Shadows produced by clouds can reduce the effective scanning range. This is due to the high contrast between sunlit area and shadows. Our eyes have difficulty adjusting to such contrasts. The same effect occurs in mountainous areas where bright sunlight causes the hills and mountains to cast dark shadows.

Heavy cloud cover can "wash out" colors on the ground, making wreckage and colored clothes or signal devices harder to sight.

5.5.4 Terrain and ground cover

If flat, open, dry areas were the only areas to be searched, the scanner’s job would be easy. Most aircraft crashes do not happen in such areas; when one does happen, it usually is found quickly without an intensive search effort.

The more intensive search efforts occur over terrain that is either mountainous or covered with dense vegetation, or both. Mountainous area searches demand frequent variation in the scanning range. This you can visualize fairly easily; at one moment the mountain or hill places the surface within, say 200 feet of the aircraft. Upon flying past the mountain or hill the surface suddenly may be a half-mile away.

Forested areas can reduce the effective scanning range dramatically. This is especially true during spring, summer, and fall when foliage is most pronounced.

The situation doesn’t change for the better in the winter where trees are of the evergreen types-pine, spruce, etc.-because the height of the trees plus their foliage masks the search objective very effectively. Frequently the only way for a scanner to actually spot an objective under such circumstance is to be looking down almost vertically. There are other signs to look for in such areas, but we will discuss them later.

5.5.5 Surface conditions

Here we are thinking of snow, primarily. Even a thin covering of new snow will change the contour, or shape, of a search objective. Also, the light-reflective quality of snow affects visual effectiveness. The net result is a need to bring the scanning range nearer to the aircraft.

5.5.6 Cleanliness of window

This might seem to be a very minor factor. On the other hand, it is estimated that the scanner's visibility can be reduced up to 50 percent if the aircraft window isn't clean. If you discover this to be the case in your aircraft, clean the window yourself. However, aircraft windows are made of plastic and they are easily scratched. Ask the pilot what cleaning materials and methods are acceptable before cleaning the window. Window cleaning is a normal part of pre- and post-flight activities.

5.5.7 Use of binoculars and cameras

Binoculars rapidly bring on eye fatigue when used in an aircraft, and may lead to disorientation and airsickness. They should only be used for *brief* periods to check sightings or for detailed viewing of an assessment area or target.

Looking through a camera or camcorder viewfinder for extended periods can be equally as discomforting. Take breaks whenever possible.

5.5.8 Use of sunglasses

Sunglasses are an important tool for aircrew, reducing eye fatigue and glare. However, sunglasses do have some negative aspects.

Looking through the aircraft windshield with polarized lenses can result in a reduced retinal image. Also, color discrimination is reduced while wearing dark lenses. And, of course, if you are looking for a lost person wearing a blue jacket, don't wear sunglasses with "blue-blocking" lenses. Finally, no matter how cool it may look, don't wear sunglasses while flying in low visibility conditions (i.e., overcast and at dawn, dusk or night).

5.5.9 Use of night vision devices

Approved night vision devices are for use *only* by scanners and observers who have completed a training program in their use.

5.5.10 Condition of the scanner

Your general physical welfare will influence how well you do your job. For example, if you have a cold or sinus trouble, you may feel so bad you cannot concentrate on scanning. In effect, this reduces your personal effective scanning range to "zero." Only you can determine your fitness to fly and do the job expected of you. If you do not believe that you feel up to the job at the moment, ask for a non-flying assignment. You will be more highly regarded if you know your own limits.

Our discussion of variables could be extended considerably because most anything that happens during a sortie could affect the scanning operation. However, the variables of major importance have been discussed.

5.6 Visual clues

5.6.1 Sighting Characteristics

If you have not had much experience at "looking down" while flying, there are some surprises in store for you. Objects appear quite different when they are seen from above and at a greater distance than usual. Even if you are very familiar with the territory as seen from the surface, scanning it from the air will reveal features and objects you had no idea were there.

Experience is the best teacher, and you will soon be able to evaluate what you see from the air. To help with your development of this ability, we will present some visual clues, what you might expect in aircraft wreckage patterns, signals which survivors might be expected to use, and some false clues that are common to selected areas.

5.6.2 Typical Visual Clues

Anything that appears to be out of the ordinary should be considered a clue to the location of the search objective. In addition to this piece of advice, the following are specific clues for which scanners should be looking:

Light colored or shiny objects - Virtually all aircraft have white or other light colors as part of their paint schemes. Some aircraft have polished aluminum surfaces that provide contrast with the usual ground surface features. Also, bright sunlight will "flash" from aluminum surfaces.

Aircraft windshields and windows, like aluminum, have a reflective quality about them. If the angle of the sun is just right, you will pick up momentary flashes with either your central or peripheral vision. A flash from any angle deserves further investigation.

Smoke and fire - Sometimes aircraft catch fire when they crash. If conditions are right, the burning airplane may cause forest or grass fires. Survivors of a crash may build a fire to warm themselves or to signal search aircraft. Campers, hunters, and fishermen build fires for their purposes, but no matter what the origin or purpose of smoke and fire, each case should be investigated.

Blackened areas - Fire causes blackened areas. You may have to check many such areas, but finding the search objective will make the effort worthwhile.

Broken tree branches - If an airplane goes down in a heavily wooded area, it will break tree branches and perhaps trees. The extent of this breakage will depend on the angle at which the trees were struck. The primary clue for the scanner, however, will be color. As you no doubt realize, the interior of a tree trunk or branch and the undersides of many types of leaves are light in color. This contrast between the light color and the darker foliage serves as a good clue.

Local discoloration of foliage - Here we are talking about dead or dying leaves and needles of evergreen trees. A crash that is several days old may have discolored a small area in the forest canopy. This discoloration could be the result of either a small fire or broken tree branches.

Fresh bare earth - An aircraft striking the ground at any angle will disturb or "plow" the earth to some degree. An overflight within a day or so of the event should provide a clue for scanners. Because of its moisture content, fresh bare earth has a different color and texture than the surrounding, undisturbed earth.

Breaks in cultivated field patterns - Crop farmlands always display a pattern of some type, especially during the growing season. Any disruption of such a pattern should be investigated. A crop such as corn could mask the presence of small aircraft wreckage. Yet the pattern made by the crashing airplane will stand out as a break in uniformity.

Water and snow - Water and snow are not visual clues, but they often contain such clues. For example, when an aircraft goes down in water its fuel and probably some oil will rise to the water's surface making an "oil slick" discoloration. Other material in the aircraft may also discolor the water or float as debris. If the aircraft hasn't been under the water very long, air bubbles will disturb the surface. Snow readily shows clues. Any discoloration caused by fire, fuel or debris will be very evident. On the other hand, do not expect easy-to-see clues if snow has fallen since the aircraft was reported missing.

Tracks and signals - Any line of apparent human tracks through snow, grass, or sand should be regarded as possibly those of survivors. Such tracks may belong to hunters, but it pays to follow them until the individual is found or you are satisfied with their termination-at a road, for example. If you do find the originator of such tracks and the person is a survivor, no doubt he will try to signal. More than likely this signal will be a frantic waving of arms.

Birds and animals - Scavenger birds (such as vultures and crows), wolves, and bears may gather at or near a crash site. Vultures (or buzzards) sense the critical condition of an injured person and gather nearby to await the person's death. If you see these birds or animals in a group, search the area thoroughly.

False clues - Examples are campfires and other purposely set fires, oil slicks that may have been caused by spillage from ships; and trash piles or pits. Aircraft parts may not have been removed from other crash sites, although some of the aircraft parts may have been marked with a yellow "X" (you may not be able to see the mark until near the site because the paint has faded or worn off with age).

In certain parts of the country, you will encounter many false clues where you would not ordinarily expect to see them. These false clues are discarded refrigerators, stoves, vehicles and pieces of other metal, such as tin roofing. What makes these false clues unique is that they are in areas far from towns and cities.

Survivors and Signals - If there are survivors and if they are capable of doing so, they will attempt to signal you. The type of signal the survivors use will depend on how much they know about the process and what type signaling devices are available to them. Here are some signaling techniques that survivors might use:

- A fire. Most people carry some means of starting a fire, and a fire probably will be the survivor's first attempt at signaling. The smoke and or flames of a fire are easily seen from the air, as we pointed out earlier.
- A group of three fires. Three fires forming a triangle is an international distress signal.
- Red smoke, white smoke, or orange smoke.

- Some types of signaling devices, such as flares, discharge colored smoke. Other flares are rocket types, and some send up a small parachute to which a magnesium flare is attached.
- Signal mirrors. If the sun is shining, a signal may be used. A special survival signal mirror includes instructions to the survivor on how to aim the signal at the search aircraft. Pocket mirrors will also work but aiming them may not be as easy.
- Panels on the ground. This type signal can be formed with white panels or with colored panels especially designed for the purpose. Of course, survivors may be able to arrange aircraft parts as a signal.

Messages - There are a number of methods and materials which survivors can use to construct messages. In snow, sand, and grassy areas, survivors may use their feet to stamp out simple messages, such as HELP or SOS. More than likely such messages will be formed with rocks, tree branches, driftwood, or any other similar materials. Such materials may also be used to construct standard ground-to-air signals. These signals are familiar to military and professional civilian pilots.

Nighttime signals - For various reasons, nighttime searches are very infrequent. If you are requested to scan for a nighttime sortie, your job will be easy. Flights will be at 3,000 AGL, or higher, and you will not need to use the scanning patterns discussed earlier. Light signals of some type will be the only clue to the search objective location.

A fire or perhaps a flashlight will be the survivor's means of signaling. On the other hand, a light signal need not be very bright; one survivor used the flint spark of his cigarette lighter as a signal. His signal was seen and he was rescued.

5.7 Wreckage patterns (accident signs)

Frequently, there are signs near a crash sight that the aircrew can use to locate the actual wreckage. The environment plays a major role in sighting the signs from the search aircraft. In crashes at sea, searchers may be unable to locate the crash site as rough seas can scatter wreckage or signs quickly. On land, the wreckage may be in dense foliage that can obscure it in a matter of days. By knowing signs to look for, the scanner can improve the effectiveness of each sortie.

Common signs of accidents include:

- Light colored or shiny objects.
- Sunlight reflections from metal.
- People.
- Distress signals.
- Blackened or burned areas.
- Broken tree branches.
- Fresh or bare earth.
- Discolored water or snow.
- Tracks or movement patterns in snow, grass, sand, etc.
- Excessive bubbles in water.

- Oil slicks, floating debris, or rafts on water.
- Smoke.
- Deep furrows in snow.
- Abnormalities in the environment.

In general, don't expect to find anything that resembles an aircraft; most wrecks look like hastily discarded trash. However, certain patterns do result from the manner in which the accident occurred.

5.7.1 Hole in the ground

Caused from steep dives into the ground or from flying straight into steep hillsides or canyon walls. Wreckage is confined to a small circular area around a deep, high-walled, narrow crater. The structure may be completely demolished with parts of the wings and empennage near the edge of the crater. Vertical dives into heavily wooded terrain will sometimes cause very little damage to the surrounding foliage, and sometimes only a day or two is needed for the foliage to repair itself.

5.7.2 Cork screw or auger

Caused from uncontrolled spins. Wreckage is considerably broken in a small area. There are curved ground scars around a shallow crater. One wing is more heavily damaged and the fuselage is broken in several places with the tail forward in the direction of the spin. In wooded areas, damage to branches and foliage is considerable, but is confined to a small area.

5.7.3 Creaming or smear

Caused from low-level "buzzing", or "flat hatting" from instrument flight, or attempted crash landing. The wreckage distribution is long and narrow with heavier components farthest away from the initial point of impact. The tail and wings remain fairly intact and sheared off close to the point of impact. With power on or a windmilling propeller, there is a short series of prop bites in the ground. Ground looping sometimes terminates the wreckage pattern with a sharp hook and may reverse the position of some wreckage components. Skipping is also quite common in open, flat terrain. In wooded areas, damage to the trees is considerable at the point of impact, but the wreckage travels among the trees beneath the foliage for a greater distance and may not be visible from the air.

5.7.4 The Four Winds

Caused from mid-air collisions, explosion, or in-flight break up. Wreckage components are broken up and scattered over a wide area along the flight path. The impact areas are small but chances of sighting them are increased by the large number of them. Extensive ground search is required to locate all components.

5.7.5 Hedge Trimming

If an aircraft strikes a high mountain ridge or obstruction but continues on for a considerable distance before crashing. Trees or the obstruction are slightly damaged or the ground on the crest is lightly scarred. Some wreckage components may be dislodged; usually landing gear, external fuel tanks, cockpit canopy, or control surfaces. The direction of flight from the hedge trimming will aid in further search for the main scene.

5.7.6 Splash

Where an aircraft has gone down into water, oil slicks, foam, and small bits of floating debris are apparent for a few hours after the impact. With time, the foam dissipates, the oil slicks spread and streak, and the debris become widely separated due to action of wind and currents. Sometimes emergency life rafts are ejected but, unless manned by survivors, will drift very rapidly with the wind. Oil slicks appear as smooth, slightly discolored areas on the surface and are in evidence for several hours after a splash; however, they are also caused by ships pumping their bilges and by offshore oil wells or natural oil seepage. Most aircraft sink very rapidly after ditching.

5.8 Reducing fatigue effects

The art of scanning is more physically demanding and requires greater concentration than mere sight seeing. In order to maintain the effectiveness of all scanning crewmembers, an observer must be aware of his own fatigue level, and that of the scanner or scanners. The following tips can help the observer direct appropriate actions and maintain scanning effectiveness:

- Change scanning positions at 30- to 60-minute intervals, if aircraft size permits.
- Rotate scanners from one side of the aircraft to the other, if two or more scanners are present.
- Find a comfortable position, and move around to stretch when necessary.
- Clean aircraft windshields and windows. Dirty windows accelerate the onset of eye fatigue, and can reduce visibility by up to 50 percent.
- Scan through open hatches whenever feasible.
- At night, use red lights and keep them dimmed to reduce reflection and glare.
- Use binoculars (sparingly) to check sightings.
- Focus on a close object (like the wing tip) on a regular basis. The muscles of the eye get tired when you focus far away for an extended period of time.
- Rest during turns outside the search area.

5.9 Directing the Pilot

The "clock position" system is used to describe the relative positions of everything outside the airplane. The system considers the clock positions to be on a horizontal plane that is centered within the cockpit. Any object above or below this plane is either "high" or "low."

Imagine yourself in the right rear seat of the airplane. Straight ahead is the twelve o'clock position; straight to the rear is six o'clock. In a real-life situation you probably would be able to see as far ahead as the one o'clock position and as far to the right as five o'clock. (Caution: never divide the clock positions into minutes; there is no such thing as a four-fifteen position.) Refer to Figure 5-10.

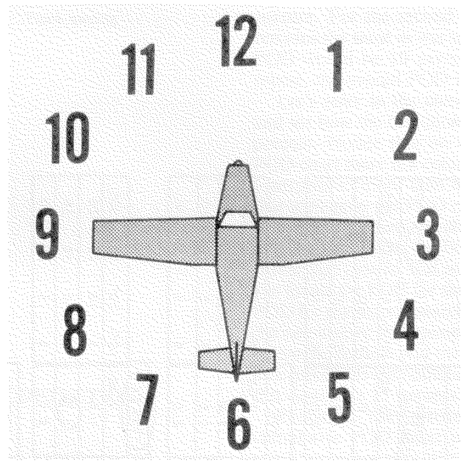

Figure 5-10

If you occupy the left-rear seat of the airplane, your clock positions probably will be seven o'clock through eleven o'clock. In either the right-rear or left-rear seat, the further designation "low" is not used for objects on the ground. They are low, but this is understood.

The clock positions are especially helpful in designating the location of other aircraft within your area of the airspace. Your pilot needs to see all other airplanes in the area so that she can keep clear of them. If you see another airplane, notify the pilot immediately. The high and low designations are also appropriate if the other airplane is considerably higher or lower than your altitude. For example, an airplane that is directly ahead but above your altitude should be called out as, "aircraft twelve o'clock high."

In spite of this system's relative simplicity, experienced crewmembers still make mistakes during stress or excitement. When reporting an observation to another crewmember, one technique that helps keep mistakes to a minimum is to precede the clock position with either "left" or "right" as appropriate. While many people may mistake three and nine o'clock, few mistake left and right. Preceding the clock position with the direction will more likely initially move all eyes in the proper direction.

Let's say you see a flash of light from the right rear, somewhere near the four o'clock position. You call out "possible target at four o'clock." The pilot starts an immediate, medium-bank turn to the right. The pilot knows the four o'clock position but her concept and your concept of this position may not be exactly the same. It looks as if the pilot might swing past your four o'clock. Now what? Don't let it happen! Say something like "straight ahead and level," or "stop turn," or "wings level." The pilot will get the idea.

Getting close to the area of your clue will require small adjustments to direction. Again, tell the pilot what to do. Pilots are accustomed to turning according to numbers of degrees, as shown by the aircraft compass, so you might want to say "five degrees right," or "ten degrees right." The pilot will turn the number of degrees you specify, level off and hold the heading.

If you see what seems to be the search objective, again give the clock position plus other helpful information, such as "near clump of trees." The pilot will bank the airplane and descend to a lower altitude. At this lower altitude identification may be possible. If the clue turns out to be the search objective, mission base will be notified by radio. Your search aircrew will try to remain in the area to direct ground teams to the site. If the clue is not the search objective, your pilot will return to the search track.

When your aircrew team locates a search objective, the scanner's duties change. He or she is no longer needed to scan the ground, but the scanner now needs to keep a sharp lookout for other aircraft. The pilot and observer will be very busy flying the airplane at low level and communicating with other mission units. The preoccupation of the pilot and observer, plus the tendency of other aircraft to congregate at a crash site, often leaves the responsibility for keeping clear of other aircraft to the scanner.

The scanner's job of looking and seeking is not over until the aircraft is parked at mission base.

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Chapter

6

6. Weather

OBJECTIVES:

1. Discuss how convection currents affect aircraft glide path.
2. Discuss wind patterns around high- and low-pressure areas.
3. Define "freezing level" and "lapse rate."
4. Discuss airframe icing and its affects on aircraft performance.
5. Discuss carburetor icing and its affects on aircraft performance.
6. Discuss the characteristics of cold, unstable cold air masses and warm, stable air masses.
7. Concerning reduced visibility conditions, state the minimums for:
    a. Visibility, under visual flight rules.
    b. Cloud bases when clouds cover over one-half the sky.
    c. How far aircraft must remain below cloud cover.
8. Discuss how reduced visibility affects search operations, and precautions for flight during reduced visibility conditions.
9. Describe how turbulence can affect search operations.
10. Discuss the dangers of wind shear.
11. Describe the 'stages' of a typical thunderstorm and discuss the dangers of flying too close.

6.1 Basic weather

Since weather plays such an important part on any flight operation, the mission scanner/observer must become familiar with some basic weather conditions. Weather can have a pronounced effect on how the search is conducted, and is one of the most important variables that influences search effectiveness.

This chapter covers weather effects in order to produce a more informed aircrew. If you know what to expect, you will be better prepared. Also, remember that the decision of whether or not to fly a particular sortie (i.e., "go, no-go") is ultimately the responsibility of the pilot-in-command. However, any crewmember may decline a mission that he or she considers too dangerous.

6.1.1 Sources of weather information

Sources of weather information are the National Weather Service, the Weather Channel, Flight Service Stations, and pilots during flight (PIREP).

6.1.2 Atmospheric circulation

The factor that upsets the normal equilibrium is the uneven heating of the earth. At the equator, the earth receives more heat than in areas to the north and south. This heat is transferred to the atmosphere, warming the air and causing it to expand and become less dense. Colder air to the north and south, being more dense, moves toward the equator forcing the less dense air upward, thus establishing a constant circulation that might consist of two circular paths; the air rising at the equator, traveling aloft toward the poles, and returning along the earth's surface to the equator. Heating at the equator would cause the air to circulate uniformly, as shown in Figure 6-1, if the earth did not rotate.

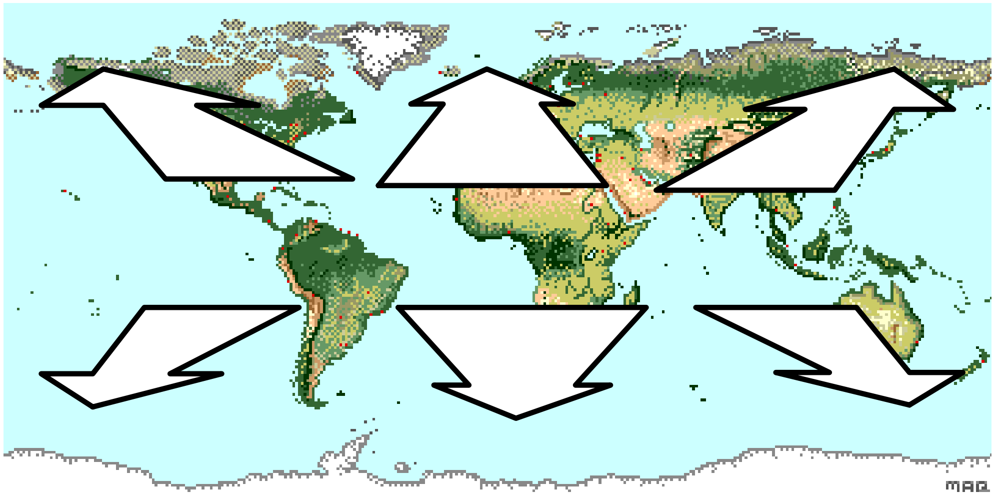


Figure 6-1

This theoretical pattern, however, is greatly modified by many forces, a very important one being the rotation of the earth. In the Northern Hemisphere, this rotation causes air to deflect to the right of its normal path. In the southern hemisphere, air is deflected to the left of its normal path. For simplicity, this discussion will be confined to the motion of air in the Northern Hemisphere.

As the air rises and moves northward from the equator, it is deflected toward the east, and by the time it has traveled about a third of the distance to the pole, it is no longer moving northward, but eastward. This causes the air to accumulate in a belt at about latitude 30º, creating an area of high pressure. Some of this air is then forced down to the earth's surface, where part flows southwestward, returning to the equator, and part flows northeastward along the surface.

A portion of the air aloft continues its journey northward, being cooled en route, and finally settles down near the pole, where it begins a return trip toward the equator. Before it has progressed very far southward, it comes into conflict with the warmer surface air flowing northward from latitude 30º. The warmer air moves up over a wedge of colder air, and continues northward, producing an accumulation of air in the upper latitudes.

Further complications in the general circulation of the air are brought about by the irregular distribution of oceans and continents, the relative effectiveness of different surfaces in transferring heat to the atmosphere, the daily variation in temperature, the seasonal changes, and many other factors.

Regions of low pressure, called “lows”, develop where air lies over land or water surfaces that are warmer than the surrounding areas. In India, for example, a low forms over the hot land during the summer months, but moves out over the warmer ocean when the land cools in winter. Lows of this type are semi-permanent, however, and are less significant to the pilot than the “migratory cyclones” or “cyclonic depressions” that form when unlike air masses meet. These lows will be discussed later.

6.1.3 Convection currents

Certain kinds of surfaces are more effective than others at heating the air directly above them. Plowed ground, sand, rocks, and barren land give off a great deal of heat, whereas water and vegetation tend to absorb and retain heat. The uneven heating of the air causes small local circulation called “convection currents”, which are similar to the general circulation just described.

This is particularly noticeable over land adjacent to a body of water. During the day, air over land becomes heated and less dense; colder air over water moves in to replace it forcing the warm air aloft and causing an on-shore wind. At night the land cools, and the water is relatively warmer. The cool air over the land, being heavier, then moves toward the water as an offshore wind, lifting the warmer air and reversing the circulation.

Convection currents cause the bumpiness experienced by aircrews flying at low altitudes in warmer weather. On a low flight over varying surfaces, the crew will encounter updrafts over pavement or barren places and down drafts over vegetation or water. Ordinarily this can be avoided by flight at higher altitudes, so aircrews may need to climb periodically to take a break from the rough air at search altitudes.

Convection currents also cause difficulty in making landings, since they affect the rate of descent. Figures 6-2 and 6-3 show what happens to an aircraft on a landing approach over two different terrain types. The pilot must constantly correct for these affects during the final approach to the airport.

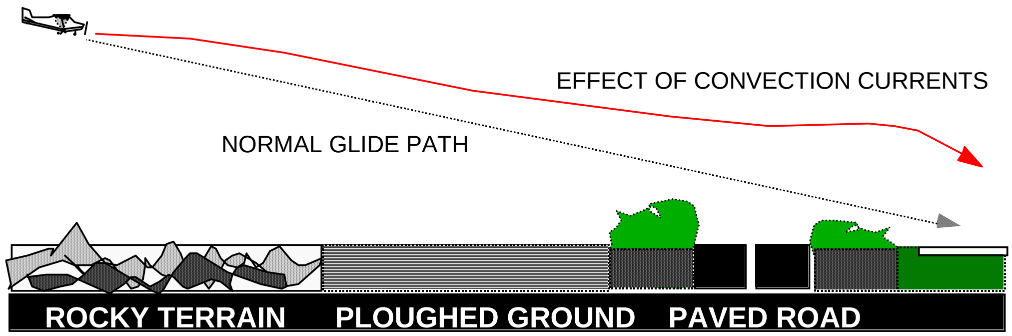


Figure 6-2

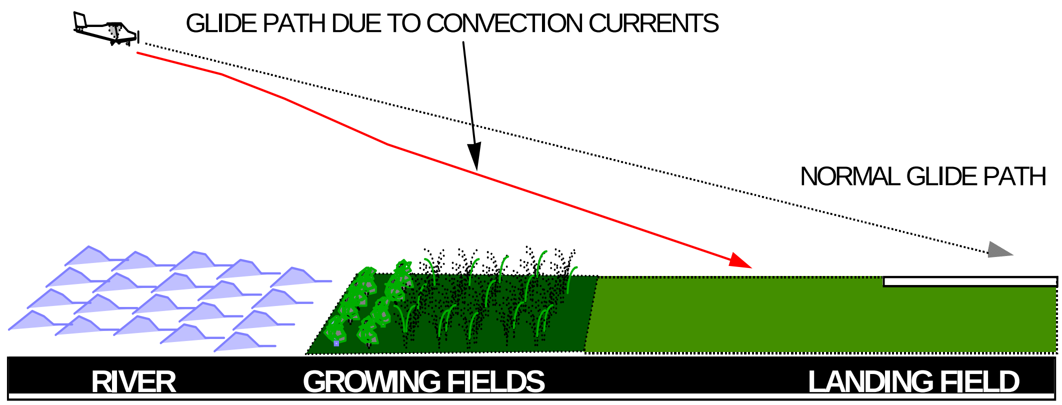


Figure 6-3

The effects of local convection, however, are less dangerous than the turbulence caused when wind is forced to flow around or over obstructions. The only way for the pilot to avoid this invisible hazard is to be forewarned, and to know where to expect unusual conditions.

6.1.4 Effect of Obstructions on Wind

When the wind flows around an obstruction, it breaks into eddies - gusts with sudden changes in speed and direction - which may be carried along some distance from the obstruction. A pilot flying through such turbulence should anticipate the bumpy and unsteady flight that may be encountered. The intensity of this turbulence depends on the size of the obstacle and the wind velocity, and it can present a serious hazard during takeoffs and landings. For example, during landings it can cause a sudden sinking, and during takeoffs it can cause the aircraft to fail to gain enough altitude to clear low objects in its path. Landings attempted under gusty conditions should be made at higher speeds in order to maintain adequate control.

This same condition is more noticeable where larger obstructions such as bluffs or mountains are involved. The wind blowing up the slope on the windward side is relatively smooth and its upward current helps to carry the aircraft over the peak. The wind on the leeward side, following the terrain contour, flows definitely downward with considerable turbulence and would tend to force an aircraft into the mountainside. The stronger the wind gets, the greater the downward pressure and turbulence. Consequently, in approaching a hill or mountain from the leeward side, a pilot should gain enough altitude well in advance. Because of these downdrafts, it is recommended that mountain ridges and peaks be cleared by at least 2,000 ft. If there is any doubt about having adequate clearance, the pilot should turn away at once and gain more altitude. Between hills or mountains, where there is a canyon or narrow valley, the wind will generally veer from its normal course and flow through the passage with increased velocity and turbulence. A pilot flying over such terrain needs to be alert for wind shifts and particularly cautious if making a landing.

6.1.5 Winds around pressure systems

Certain wind patterns can be associated with areas of high and low pressure. As previously stated, air flows from an area of high pressure to an area of low pressure. In the Northern Hemisphere during this flow the air is deflected to the right because of the rotation of the earth. Therefore, as the air leaves the high-pressure area, it is deflected to produce a clockwise circulation.

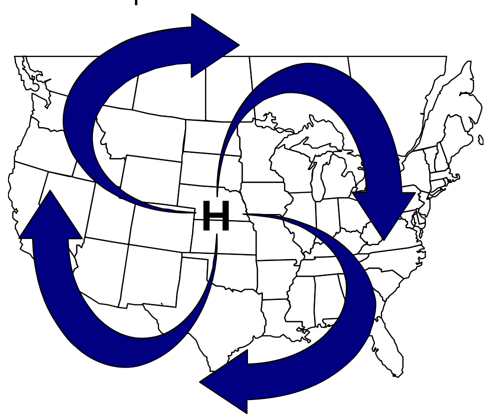


Figure 6-4

As the air flows toward the low-pressure area, it is deflected to produce a counterclockwise flow around the low-pressure area.

Figure 6-5

Another important aspect is air moving out of a high-pressure area depletes the quantity of air. Therefore, highs are areas of descending air. Descending air favors dissipation of cloudiness; hence the association that high pressure usually portends good weather.

By similar reasoning, when air converges into a low-pressure area, it cannot go outward against the pressure gradient, nor can it go downward into the ground; it must go upward. Rising air is conducive to cloudiness and precipitation; thus the general association low pressure — bad weather.

Knowledge of these patterns frequently enables a pilot to plan a course to take advantage of favorable winds, particularly during long flights. In flying from east to west, for example, the pilot will find favorable winds to the south of a high, or to the north of a low. It also gives the pilot a general idea of the type of weather to expect relative to the “highs” and “lows.”

The theory of general circulation in the atmosphere and the wind patterns formed within areas of high pressure and low pressure has been discussed. These concepts account for the large-scale movements of the wind, but do not take into consideration the effects of local conditions that frequently cause drastic modifications in wind direction and speed near the earth's surface.

6.2 Icing

6.2.1 Freezing level

As altitude increases, temperature decreases at a fairly uniform rate of 2° Celsius or 3.6° Fahrenheit for each 1000 feet. This rate of temperature change is known as the *lapse rate*. At some altitude, the air temperature reaches the freezing temperature of water, and that altitude is known as the *freezing level*. You can estimate the freezing level prior to flight by using simple mathematics. For example, if the airport elevation is 1,000 feet and the temperature at ground level is 12° Celsius, the freezing level would be at approximately 6,000 feet above ground level (AGL) or 7,000 feet above mean sea level (MSL). Since the lapse rate is 2° per thousand feet, it would take 6,000 feet of altitude to go from 12° Celsius to 0°, the freezing temperature of water. The same technique works for Fahrenheit, but you use 3.6° for the lapse rate. Don’t forget to include the airport elevation in your computations—altimeters are normally set to display MSL rather than AGL altitude. This method yields a very approximate value for the freezing level. You are encouraged to leave a wide margin for error above and below this altitude if you must fly through visible moisture during a search.

6.2.2 Airframe icing

When the ground cools at night, the temperature of the air immediately adjacent to the ground is frequently lowered to the saturation point, causing condensation. This condensation takes place directly upon objects on the ground as dew if the temperature is above freezing, or as frost if the temperature is below freezing.

Dew is of no importance to aircraft, but frost can be deadly. Normally we think of frost as unimportant - it forms on cars or other cold surfaces overnight, soon melting after the sun rises. However, frost on an airplane disturbs the airflow enough to reduce the lift and efficiency of aerodynamic surfaces. An airplane *may* be able to fly with frost on its wings, but, even with the airflow over the wings only slightly disrupted, controllability can become unpredictable. *Frost should always be removed before flight*. Some precautions should be taken if frost is expected, such as placing the aircraft in a hangar (even a T-hangar).

Ice increases drag and decreases lift, and ice on the prop reduces thrust. Ice decreases aircraft performance, and stall speed goes up. Ice deposits on a typical C172 significantly increase the weight of the aircraft; a quarter-inch coating of ice can add up to 150 lbs., a half-inch can add 300 lbs., and an inch of clear ice can add 600 lbs. (approximate figures).

Ice can also accumulate on aircraft during flight, and this icing is a major problem in aviation. It is difficult to forecast, because under apparently identical situations the icing intensity on the aircraft can vary considerably. The ice accumulation rate may vary from less than one-half inch per hour to as high as one inch in a minute for brief periods. Experiments have shown that an ice deposit of as little as one-half inch on the leading edge of a wing can reduce lift by about 50%, increase drag by an equal percentage, and thus greatly increase the stall speed. Obviously, the consequences of ice accumulations can be very serious.

There are only two fundamental requisites for ice formation on an aircraft in flight. First the aircraft must be flying through visible water in the form of rain or cloud droplet, and second, when the liquid water droplets strike, their temperature, or the temperature of the airfoil surface, must be 32º F. or below. Water droplets cooled below 32º F. without freezing are called super cooled water droplets. They often exist in clouds when the temperature within the clouds is below 32º F.

Clear ice is a transparent or translucent coating of ice that has a glassy surface appearance. When transparent, it looks like ordinary ice, and is identical with the "glaze" which forms on trees and other objects when freezing rain falls to the earth. It can be smooth or stippled. However, when mixed with snow, sleet, hail, etc., it may be rough, irregular and whitish. It has an appearance different from that of rime ice, due to its different mode of formation and structure. It adheres very firmly to the surfaces upon which it forms, and is very difficult to remove. Glaze usually forms on the leading edges of wings, antennas, etc., more or less in the shape of a blunt nose, and spreads back tapering along the wings. When deposited as a result of freezing of super-cooled raindrops or large cloud droplets unmixed with solid precipitation, it can be quite smooth and approximate a streamline form. When mixed with solid precipitation the deposit can become especially blunt-nosed and rough, with heavy protuberances that build out across the normal streamlines of airflow.

Rime ice is a white or milky, opaque, granular deposit of ice which accumulates on the leading edges of wings, antennas, etc., of an aircraft. Its surface is ordinarily rough. It has a granulated, crystalline or splintery structure. Rime ice usually accumulates on the leading edges of exposed parts and projects forward into the air stream. It usually builds outward from the leading edge into a sharp-nosed shape. Wherever the particles of super cooled water impinge on surface projections of the aircraft, like rivet heads, the deposit acquires the form of a bulge, which may cling rather firmly to the projecting parts.

When ice forms on an aircraft it can affect the flying characteristics in several ways:

- Weight is added. Clear ice can add substantial weight to an aircraft. The added weight increases lift requirements and increases drag. This is what makes the added weight of ice so dangerous.
- Lift is decreased. This is caused by a change in airfoil shape when ice accumulates on the leading edges. (The aircraft will stall at air speeds well above the normal stalling point.)
- The drag is increased. This results when rough ice forms in back of the leading edges and on protuberances.
- Propeller efficiency is decreased. Uneven ice deposits on the blades cause vibration and blade distortion and consequent loss of effective power. Under icing conditions all available power may be needed.

Sorties should never be flown in regions of possible icing. The only reason an aircrew may experience icing is during transits, such as to a mission base (even this should be avoided). However, if the pilot does encounter potential icing conditions, he should plan your flight so as to be in the region for the shortest possible time.

- Caution should be exercised when flying through rain or wet snow with the temperature at flight levels near freezing.
- When flying into clouds above the crest of ridges or mountains, maintain a clearance of 4,000 or 5,000 feet above the ridges if the temperature within the cloud is below freezing. Icing is more probable over the crest of ridges than over the adjacent valleys.
- Watch for ice when flying through cumulus clouds with the temperature at flight level near freezing.
- When ice is formed on the aircraft, avoid maneuvers that will increase the wing loading.
- Remember that fuel consumption is greater when flying under icing conditions, due to increased drag and the additional power required.
- Consult the latest forecasts for expected icing conditions.

6.2.3 Carburetor icing

Although not directly related to weather, another ice problem is carburetor icing. As air is drawn through the carburetor Venturi, it expands and cools by as much as 60º F (Venturi effect). Moisture in the air can condense, then freeze, blocking further flow of air and fuel to the engine.

Unlike aircraft structural icing, carburetor ice can form on a warm day in moist air. In the winter when temperatures are below 40º F. the air is usually too cold to contain enough moisture for carburetor ice to form. In the summer when temperatures are above 85º F. there is too much heat for ice to form. So, airplanes are most vulnerable to carburetor icing when operated in high humidity or visible moisture with temperatures between 45º and 85º F.

Normally, an airplane engine develops sufficient heat at climb and cruise power settings to keep carburetor ice from forming. It's most likely to become a problem when the aircraft is operated at low power settings, such as in descents and approaches to landings.

Many manufacturers have provided a means for selectively ducting warm air to the carburetor to prevent ice build-up when operating at low power settings. This feature is called *carburetor heat,* and the pilot may select it when starting a low-power descent. Fuel injected engines are not vulnerable to carburetor icing.

6.3 Frontal activity

Large, high-pressure systems frequently stagnate over large areas of land or water with relatively uniform surface conditions. They take on characteristics of these “source regions” (e.g., the coldness of polar regions, the heat of the tropics, the moisture of oceans, or the dryness of continents).

As air masses move away from their source regions and pass over land or sea, they are constantly being modified through heating or cooling from below, lifting or subsiding, absorbing or losing moisture. Actual temperature of the air mass is less important than its temperature in relation to the land or water surface over which it is passing. For example, an air mass moving from a polar region is usually colder than the land and sea surfaces over which it passes. On the other hand, an air mass moving from the Gulf of Mexico in winter usually is warmer than the territory over which it passes.

If the air is colder than the surface, it will be warmed from below and convection currents will be set up, causing turbulence. Dust, smoke, and atmospheric pollution near the ground will be carried upward by these currents and dissipated at higher levels, improving surface visibility. Such air is called "unstable." Conversely, if the air is warmer than the surface, there is no tendency for convection currents to form, and the air is smooth. Smoke, dust, etc., are concentrated in lower levels with resulting poor visibility. Such air is called "stable." From the combination of the source characteristics and the temperature relationship just described, air masses can be associated with certain types of weather.

When two air masses meet, they will not mix readily unless their temperature, pressure, and relative humidity are very similar. Instead, they set up boundaries called frontal zones, or "fronts", the colder air mass projecting under the warmer air mass in the form of a wedge. This condition is termed a "stationary front" if the boundary is not moving.

Usually, the boundary moves along the earth's surface, and as one air mass withdraws from a given area it is replaced by another air mass. This action creates a moving front. If warmer air is replacing colder air, the front is called "warm"; if colder air is replacing warmer air, the front is called "cold."

Certain characteristics of frontal activities will affect search effectiveness (primarily visibility and turbulence). For the both the mission staff and the aircrew, these factors must be considered during mission planning.

Characteristics of a cold, unstable air mass:

- Cumulus and cumulonimbus clouds.
- Unlimited ceilings (except during precipitation).
- Excellent visibility (except during precipitation).
- Unstable air resulting in pronounced turbulence in lower levels (because of convention currents).
- Occasional local thunderstorms or showers - hail sleet, snow flurries.

Characteristics of a warm, stable air mass:

- Stratus and stratocumulus clouds.
- Generally low ceilings.
- Poor visibility (fog, haze, smoke, and dust held in lower levels).
- Smooth, stable air with little or no turbulence.
- Slow steady precipitation or drizzle.

6.3.1 Warm Front

When a warm front moves forward, the warm air slides up over the wedge of colder air lying ahead of it.

Warm air usually has high humidity. As this warm air is lifted, its temperature is lowered. As the lifting process continues, condensation occurs, low nimbostratus and stratus clouds form and drizzle or rain develops. The rain falls through the colder air below, increasing its moisture content so that it also becomes saturated. Any reduction of temperature in the colder air, which might be caused by up-slope motion or cooling of the ground after sunset, may result in extensive fog.

As the warm air progresses up the slope, with constantly falling temperature, clouds appear at increasing heights in the form of altostratus and cirrostratus, if the warm air is stable. If the warm air is unstable, cumulonimbus clouds and altocumulus clouds will form and frequently produce thunderstorms. Finally, the air is forced up near the stratosphere, and in the freezing temperatures at that level, the condensation appears as thin wisps of cirrus clouds. The up-slope movement is very gradual, rising about 1,000 ft. every 20 miles. Thus, the cirrus clouds, forming at perhaps 25,000 ft. altitude, may appear as far as 500 miles in advance of the point on the ground which marks the position of the front.

6.3.2 Flight toward an approaching warm front

Although no two fronts are exactly alike, a clearer understanding of the general weather pattern may be gained if the atmospheric conditions that might exist when a warm front is moving eastward from St. Louis, Mo., is considered.

- At St. Louis, the weather would be very unpleasant, with drizzle and probably fog.
- At Indianapolis, 200 miles in advance of the warm front, the sky would be overcast with nimbostratus clouds, and continuous rain.
- At Columbus, 400 miles in advance, the sky would be overcast with predominantly stratus and altostratus clouds. The beginning of a steady rain would be probable.
- At Pittsburgh, 600 miles ahead of the front, there would probably be high cirrus and cirrostratus clouds.

If a flight were made from Pittsburgh to St. Louis, ceiling and visibility would decrease steadily. Starting under bright skies, with unlimited ceilings and visibilities, lowering stratus-type clouds would be noted as Columbus was approached, and soon afterward precipitation would be encountered. After arriving at Indianapolis, the ceilings would be too low for further flight. Precipitation would reduce visibilities to practically zero. Thus, it would be wise to remain in Indianapolis until the warm front had passed, which might require a day or two.

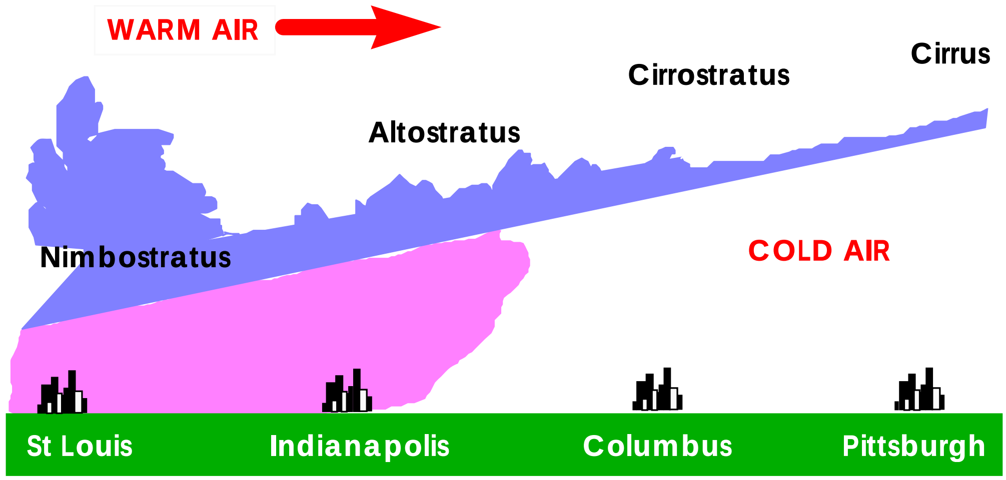


Figure 6-6

If a return flight to Pittsburgh was made, it would be recommended to wait until the front had passed beyond Pittsburgh, which might require three or four days. Warm fronts generally move at the rate of 10 to 25 miles an hour.

On the trip from Pittsburgh to Indianapolis a gradual increase in temperature would have been noticed, and a much faster increase in dew point until the two coincided. Also the atmospheric pressure would be gradually lessening because the warmer air aloft would have less weight than the colder air it was replacing. This condition illustrates the general principle that a falling barometer indicates the approach of stormy weather.

6.3.3 Cold Front

When the cold front moves forward it functions like the blade of a snowplow, sliding under the warmer air and forcing it aloft. This causes the warm air to cool suddenly and form cloud types that depend on the stability of the warm air.

In fast-moving cold fronts, friction retards the front near the ground, which brings about a steeper frontal surface. This steep frontal surface results in a narrower band of weather concentrated along the forward edge of the front. If the warm air is stable, an overcast sky may occur for some distance ahead of the front, accompanied by general rain. If the warm air is conditionally unstable, scattered thunderstorms and showers may form in the warm air. At times an almost continuous line of thunderstorms may form along the front or ahead of it. These lines of thunderstorms (squall lines) contain some of the most turbulent weather experienced by pilots. Behind the fast-moving cold front there is usually rapid clearing, with gusty and turbulent surface winds, and colder temperatures.

The slope of a cold front is much steeper than that of a warm front and the progress is generally more rapid -usually from 20 to 35 miles per hour, although in extreme cases, cold fronts have been known to move at 60 miles per hour. Weather activity is more violent and usually takes place directly at the front instead of in advance of the front. In late afternoon during the warm season, however, squall lines frequently develop as much as 50 to 200 miles in advance of the actual cold front. Whereas warm front dangers are low ceilings and visibilities, cold front dangers are chiefly sudden storms, high and gusty winds, and turbulence.

Unlike the warm front, the cold front rushes in almost unannounced, makes a complete change in the weather within a period of a few hours, and moves on. Altostratus clouds sometimes form slightly ahead of the front, bur these are seldom more than 100 miles in advance. After the front has passed, the weather often clears rapidly and cooler, drier air with usually unlimited ceilings and visibilities prevail.

6.3.4 Flight Toward an Approaching Cold Front

If a flight was made from Pittsburgh toward St. Louis when a cold front was approaching from St. Louis, weather conditions quite different from those associated with a warm front will be experienced. The sky in Pittsburgh would probably be somewhat overcast with stratocumulus clouds typical of a warm air mass, the air smooth, and the ceilings and visibilities relatively low although suitable for flight.

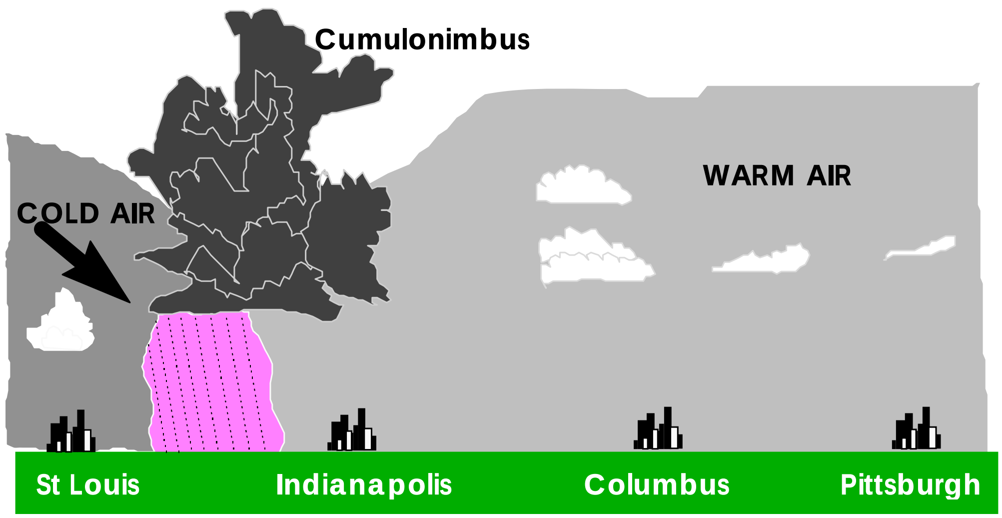


Figure 6-7

As the flight proceeded, these conditions would prevail until reaching Indianapolis. At this point, it would be wise to check the position of the cold front by consulting a recent weather map and Teletype sequences, or the meteorologist. It would probably be found that the front was now about 75 miles west of Indianapolis. A pilot with sound judgment based on knowledge of frontal conditions, would remain in Indianapolis until the front had passed - a matter of a few hours - and then continue to the destination under near perfect flying conditions.

If, however, through the lack of better judgment the flight were continued toward the approaching cold front, a few altostratus clouds and a dark layer of nimbostratus lying low on the horizon, with perhaps cumulonimbus in the background would be noted. Two courses would now be open:

- Either to turn around and outdistance the storm, or
- Make an immediate landing that might be extremely dangerous because of gusts and sudden wind shifts.

The wind in a “high” blows in a clockwise spiral. When two highs are adjacent, the winds are in almost direct opposition at the point of contact. Since fronts normally lie between two areas of higher pressure, wind shifts occur in all types of fronts, but they usually are more pronounced in cold fronts.

If flight was continued, entrapment in a line of squalls and cumulonimbus clouds could occur. It may be disastrous to fly beneath these clouds; impossible, in a small plane, to fly above them. At low altitudes, there are not safe passages through them. Usually there is no possibility of flying around them because they often extend in a line for 300 to 500 miles.

6.3.5 Occluded Front

One other form of front with which the pilot should become familiar is the "exclusion" or "occluded front." This is a condition in which an air mass is trapped between two colder air masses and forced aloft to higher and higher levels until it finally spreads out and loses its identity. An occluded front appears on weather maps as shown in Figure 6-8.

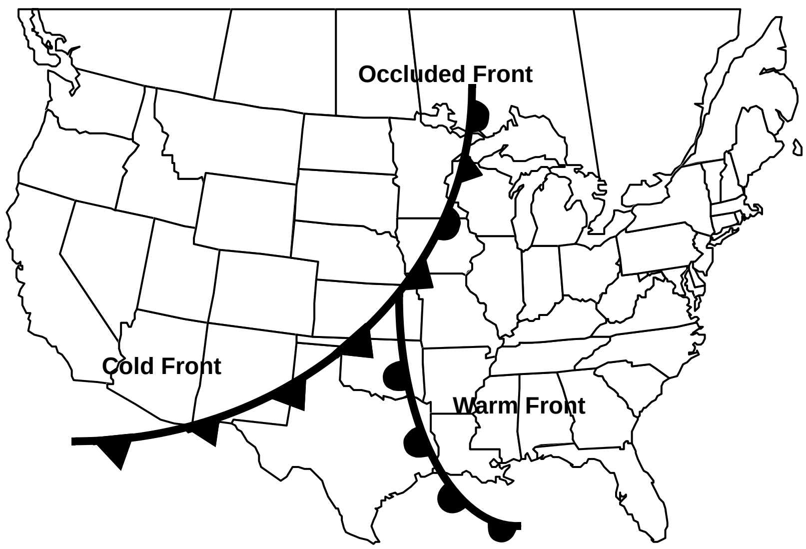


Figure 6-8

Meteorologists subdivide occlusions into two types, but so far as the pilot is concerned, the weather in any occlusion is a combination of warm front and cold front conditions. As the occlusion approaches, the usual warm front indications prevail - lowering ceilings, lowering visibility, and precipitation. Generally the cold front type, with squalls, turbulence, and thunderstorms, then follows the warm front weather almost immediately.

The first stage represents a boundary between two air masses, the cold and warm air moving in opposite directions along a front. Soon, however, the cooler air, being more aggressive, thrusts a wedge under the warm air, breaking the continuity of the boundary. Once begun, the process continues rapidly to the complete occlusion. As the warmer air is forced aloft, it cools quickly and its moisture condenses, often causing heavy precipitation. The air becomes extremely turbulent, with sudden changes in pressure and temperature.

6.4 Reduced Visibility

According to FAA regulations, under almost all circumstances flight using visual flight rules can only be conducted with at least three miles of visibility. If clouds cover more than one-half the sky, the cloud bases must be no lower than 1,000 feet above the terrain. In addition, search aircraft must usually remain at least 500 feet below the cloud deck.

One of the most common hazardous-weather problems is loss of visibility. This can happen either suddenly or very insidiously, depriving the pilot of his ability to see and avoid other aircraft, and reducing or depriving him altogether of his ability to control the aircraft, unless he has had training and is proficient in instrument flying. In reduced visibility, the crew's ability to see rising terrain and to avoid towers, power transmission lines, and other man-made obstacles is diminished.

Visibility may be reduced by many conditions including clouds, rain, snow, fog, haze, smoke, blowing dust, sand, and snow. A similar condition called "white out" can occur where there has been snowfall.

In most regions of the country, fog and haze are the most common weather conditions that cause reduced visibility. Fog, especially dense fog, can pose a hazard to even the most sophisticated military or civilian aircraft. In thick fog, reduced visibility may make it extremely difficult, if not impossible, to see landing runways or areas. The crew should be alert for a potential problem with fog whenever the air is relatively still, the temperature and dew point are within several degrees, and the temperature is expected to drop further, as around sunset and shortly after sunrise. This is often a factor in delaying the first sorties of the day.

Haze, a fine, smoke-like dust causes lack of transparency in the air. It's most often caused when still air prevents normal atmospheric mixing, allowing the particles to persist, instead of the wind's dispersing them. Like fog, it is most likely to occur when the air is still. The air doesn't mix to scatter the particles of dust, smoke, or pollen. If the wind remains calm for several days, visibility will become progressively worse. This atmospheric condition is most common in heavily populated, industrialized areas of the country. It can also be present anywhere there is still air and a source of particles, like near burning farm fields or thick forests that produce large quantities of pollen. It is especially noticeable in the early morning.

Frequently, as the sun warms the cool, hazy air and causes it to expand and rise, visibility at the surface will improve and appear acceptable. What initially appeared to be ample visibility can, after takeoff, become almost a complete obstruction to lateral or forward visibility several hundred feet above the surface. Downward visibility is satisfactory, but pilots may feel apprehensive about the loss of a visible horizon to help judge aircraft control, and about what might come out of the murk ahead. Visibility at this altitude may actually be more than the minimum three miles, yet the pilot may interpret this visual range as a wall just beyond the airplane's nose.

In summer, haze and smoke may extend upward more than 10,000 feet during the heat of the day, hiding rain showers or thunderstorms within the haze and presenting a special hazard. When haze and smoke are present, the best measure a flight crew can take to minimize risk of such an encounter is to get a thorough weather briefing before flying, and update the briefing by radio with *Flight Watch* as required.

Blowing dust is normally found in the relatively dry areas of the country, like the desert southwest. The condition develops when strong wind picks up small soil particles, and strong air currents carry it upward into the atmosphere. These conditions can spread dust hundreds of miles and up to 15,000 feet. Depending upon wind speed and particle volume, visibility in dust storms may be reduced to very low levels. Blowing sand is much more localized than dust, occurring only when the wind is strong enough to lift loose sand. Since sand particles are much heavier than dust they are rarely lifted more than 50 feet above the surface. Still, the condition eliminates the effectiveness of visual searches, and in many cases can prohibit an aircraft from taking off or landing.

Strong surface winds can also cause blowing snow. Blowing snow is more frequent in areas where dry, powdery snow is found. For the aviator, blowing snow can cause the same problems of reduced visibility. Like dust, it can reach thousands of feet above the surface.

Snow can cause another visibility problem, known as “white out.” This condition can occur anywhere there is snow-covered ground, but is most common in arctic regions. It's not a physical obstruction to visibility like earlier examples, but an optical phenomenon. White out requires a snow-covered surface and low-level clouds of uniform thickness. At low sun angles, light rays are diffused as they penetrate the cloud layer causing them to strike the snow-covered surface at many angles and eliminating all shadows. The net effects are loss of a visible horizon and loss of depth perception, each of which can make low-level flight and landings difficult and hazardous.

From this discussion, it becomes obvious that each member of the aircrew must be vigilant during all phases of the flight when visibility is less than perfect. Crew resource management requires that each member of the crew be assigned an area to search during the takeoff, transit and approach-to-landing phases of the flight in order to help the pilot "see and avoid" obstacles and other aircraft.

The aircrew must also characterize visibility in the search area so as to establish the proper scanning range (see the chapter on Scanning Techniques and Sighting Characteristics). Search visibility may be different than expected, and your search pattern may have to be adjusted accordingly. Be sure to cover this during your debriefing.

6.5 Turbulence

Turbulence is irregular atmospheric motion or disturbed wind flow that can be attributed to a number of causes. Under almost all circumstances, small amounts of normal atmospheric turbulence can be expected and it usually poses few problems. Previous sections covered wake turbulence and convective activity as causes of turbulence. Convective activity was covered in the context of thunderstorm development, but any phenomenon that causes air to be lifted up, even a hot asphalt parking lot, can cause convective turbulence. Other causes include obstructions to wind flow and wind shear.

Just as a tree branch dangling into a stream creates continuous ripples or waves of turbulence in the water’s surface, obstructions to the wind can create turbulence in the air. This type of turbulence occurs mostly close to the ground, although depending upon wind velocity and the nature of the obstruction, it may reach upward several thousand feet. In an extreme case, when winds blow against a mountainside, the mountain deflects the wind upward creating a relatively smooth updraft. Once the wind passes the summit, it tumbles down the leeward or downwind side, forming a churning, turbulent down draft of potentially violent intensity. The churning turbulence can then develop into *mountain waves* that may continue many miles from the mountain ridge. Mountain waves may be a factor when surface winds are as little as 15 knots.

Turbulence can be inconsequential, mildly distracting, nauseating, or destructive depending on its intensity. Turbulence can often be avoided by changing altitudes. Aircraft manufacturers publish *maneuvering speeds* in the operating handbooks. If the maneuvering airspeed of an aircraft is exceeded in turbulent air, structural damage could occur.

Turbulence can become a major factor in search effectiveness. Any scanner or observer who is uncomfortable or nauseous cannot perform their duties at a very high level of effectiveness. If you experience these sensations, inform the pilot immediately. If turbulence detracted from your concentration during the search, be sure to mention this during debriefing.

6.6 Wind Shear

Wind Shear is best described as a change in wind direction and/or speed within a very short distance in the atmosphere. Under certain conditions, the atmosphere is capable of producing some dramatic shears very close to the ground; for example, wind direction changes of 180º and speed changes of 50 knots or more within 200 ft. of the ground have been observed. This, however, is not something encountered every day. In fact, it is unusual, which makes it more of a problem. It has been thought that wind cannot affect an aircraft once it is flying except for drift and groundspeed. This is true with steady winds or winds that change gradually. It isn't true, however, if the wind changes faster than the aircraft mass can be accelerated or decelerated.

The most prominent meteorological phenomena that cause significant low-level wind shear problems are thunderstorms and certain frontal systems at or near an airport.

Basically, there are two potentially hazardous shear situations. First, a tailwind may shear to either a calm or headwind component. In this instance airspeed initially increases, the aircraft pitches up and the altitude increases. Second, a headwind may shear to a calm or tailwind component. In this situation the airspeed initially decreases, the aircraft pitches down and the altitude decreases. Aircraft speed, aerodynamic characteristics, power/weight ratio, power plant response time, and pilot reactions along with other factors have a bearing on wind shear effects. It is important, however, to remember that shear can cause problems for any aircraft and any pilot.

There are two atmospheric conditions that cause these types of low-level wind shear: thunderstorms and fronts.

The winds around a thunderstorm are complex (discussed in the following section). Wind shear can be found on all sides of a cell. The wind shift line or gust front associated with thunderstorms can precede the actual storm by up to 15 nautical miles. Consequently, if a thunderstorm is near an airport of intended landing or takeoff, low-level wind shear hazards may exist.

While the direction of the winds above and below a front can be accurately determined, existing procedures do not provide precise and current measurements of the height of the front above an airport. The following is a method of determining the approximate height of the front, considering that wind shear is most critical when it occurs close to the ground.

- A cold front wind shear occurs just after the front passes the airport and for a short period thereafter. If the front is moving 30 knots or more, the frontal surface will usually be 5,000 ft. above the airport about 3 hours after the passage.
- With a warm front, the most critical period is before the front passes the airport. Warm front shear may exist below 5,000 ft. for approximately 6 hours; the problem ceases to exist after the front passes the airport. Data compiled on wind shear indicate that the amount of shear in warm fronts is much greater than that found in cold fronts.
- Turbulence may or may not exist in wind shear conditions. If the surface wind under the front is strong and gusty there will be some turbulence associated with wind shear.

The pilot should be alert to the possibilities of low-level wind shear at any time the conditions stated are present.

6.7 Thunderstorms

A thunderstorm is any storm accompanied by thunder and lighting. It usually includes some form of precipitation, and can cause trouble for aircraft in many forms: turbulence, icing, poor visibility, hail, wind shear, microbursts, lightning, and, in severe cases, tornadoes.

Individual thunderstorms may often be very local in nature, although they often form along weather fronts and appear to march across the land in long lines. This is the situation when weather forecasters announce that a line of thunderstorms is approaching, and thunderstorm warnings go into effect. Individual thunderstorms are rarely larger than 10 miles in diameter, and typically develop, mature, and dissipate within an hour and a half at the most. Each is produced by the growth of a puffy cumulus cloud into a cumulonimbus cloud. The severe elements of a thunderstorm result from the vertical air movement, or convective activity, within the storm.

Thunderstorms may be studied by dividing them into three separate growth stages: the cumulus, or building stage, the mature stage, and the dissipating stage. Figure 6-9 depicts the physical appearances of each stage of the developing storm.

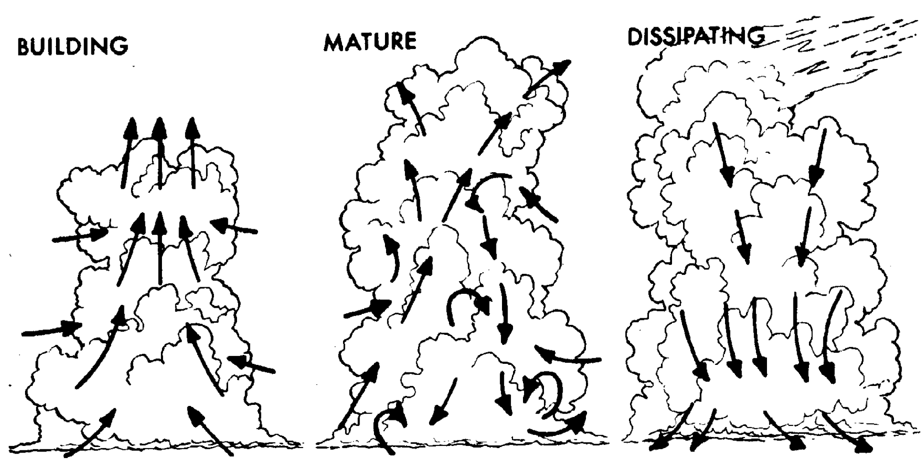


Figure 6-9

Most cumulus clouds do not become thunderstorms, but all thunderstorms are born as cumulus clouds. The main feature of this first stage of thunderstorm development is its updraft, a large air current flowing upward from the ground through the chimney-like cloud. The draft can reach speeds of several thousand feet per minute, and continue to an altitude of 40,000 feet or more. During this period, small water droplets grow into raindrops as the cloud builds upward to become a cumulonimbus cloud.

Precipitation at the earth's surface marks the mature stage of a thunderstorm. The raindrops (or ice particles) have now become so large and heavy that the updraft can no longer support them, and they begin to fall. As they fall, the raindrops drag air with them, causing the characteristic strong down draft of mature thunderstorms. These down drafts spread out horizontally when they reach the surface, producing strong, gusty winds, wind shear, sharp drops in temperature (because the air was chilled at high altitudes) and a sharp rise in pressure.

The mature stage of the thunderstorm is when associated hazards are most likely to reach maximum intensity. Microbursts, extremely intense down drafts, can occur during this mature phase of development. Downward wind velocities in microbursts may reach 6,000 feet per minute, and even powerful jet aircraft may have insufficient power to recover prior to ground impact.

As down drafts continue to spread, updrafts weaken, and the entire thunderstorm eventually becomes an area of down drafts, which characterizes the dissipating stage of the thunderstorm. During this stage, the cloud develops the characteristic anvil shape at the top and may take on a stratiform or layered appearance at the bottom. Usually this stage is the longest of the three stages of a thunderstorm's life.

No thunderstorm should ever be taken lightly. During the cumulus stage, vertical growth occurs so quickly that climbing over the developing thunderstorm is not possible. Flight beneath a thunderstorm, especially in the mature stage, is considered very foolish, due to the violent down drafts and turbulence beneath them. Flight around them may be a possibility, but can still be dangerous. Even though the aircraft may be in clear air, it may encounter hail, lightning, or turbulence a significant distance from the storm's core. Thunderstorms should be avoided by at least 20 miles laterally. The safest alternative, when confronted by thunderstorms, is to land, tie the aircraft down, and wait for the storms to dissipate or move on.

Chapter

7

7. High Altitude and Terrain Considerations

OBJECTIVES:

1. Concerning atmospheric pressure:
    a. State the pressure at sea level, and describe how to compensate for 'other-than-sea level pressures' when setting the altimeter.
    b. Discuss the three factors that affect the density of an air mass.
    c. Define density altitude, and compute density altitude for a given situation using a chart and a flight calculator.
2. State the phases of flight affected by a decrease in atmospheric pressure, and how aircraft performance is affected.
3. Discuss strategies to compensate for high DA during searches.
4. Discuss the symptoms and dangers of dehydration, and strategies used to combat its effects.
5. Discuss the symptoms and dangers of ear block, sinus block and hypoxia, and strategies used to combat their effects.
6. Discuss mountainous terrain precautions and strategies.

7.1 Atmospheric pressure

Pressure at a given point is a measure of the weight of the column of air above that point. As altitude increases, pressure diminishes as the weight of the air column decreases. This decrease in pressure has a pronounced effect on flight. The aircraft's altimeter is sensitive to these changes in pressure, and displays this pressure as altitude. When the aircraft's altimeter is set to the current reported altimeter setting (ATIS/AWOS/ASOS/FSS) it indicates the aircraft's height above mean sea level (MSL). [If a local altimeter setting is unavailable, pilots usually set the altimeter to indicate the airport's MSL elevation.]

Changes in pressure are registered in inches of mercury: the *standard* sea-level pressure is 29.92 inches at a *standard* temperature of 15º C (59º F). If aircraft always operated at standard conditions, the altimeter would always be accurate. An aircraft with an indicated (on the altimeter) altitude of 5,000' MSL will really be 5000' above the ground (AGL). However, these standard conditions rarely exist because the density of the atmosphere is always changing as altitude and temperature changes. [The third factor - humidity - also effects density, but the effect is smaller and it's very hard to determine.]

Pressure altitude is an altitude measured from the point at which an atmospheric pressure of 29.92 inches of mercury is found. A good rule of thumb is that a 1,000' change of altitude results in a 1-inch (mercury) change on a barometer. Another way to determine pressure altitude is to enter 29.92 into the altimeter's window and read the resulting altitude indication.

When pressure altitude is corrected for non-standard temperature, *density altitude* can be determined. There are two ways to do this.

Chart method

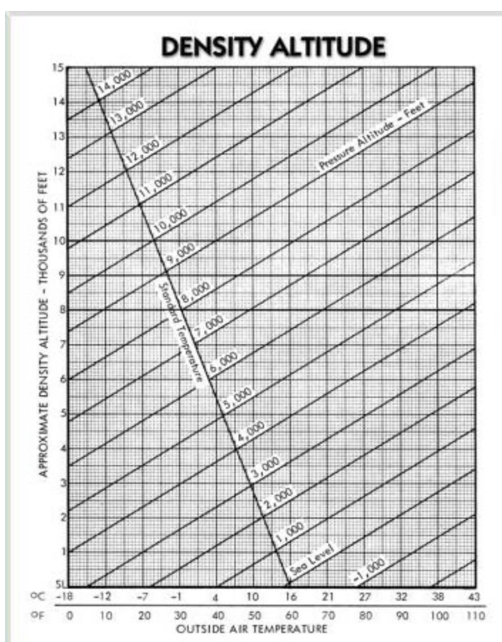


Figure 7-1

Assume an aircraft is taking off from an airport with a pressure altitude of 3,000' and the temperature is 80º F. Draw a line straight up from 80º F to the intersection of the 3,000' pressure altitude line. Then proceed horizontally to the left to read the density altitude (5,000').

Flight Computer method

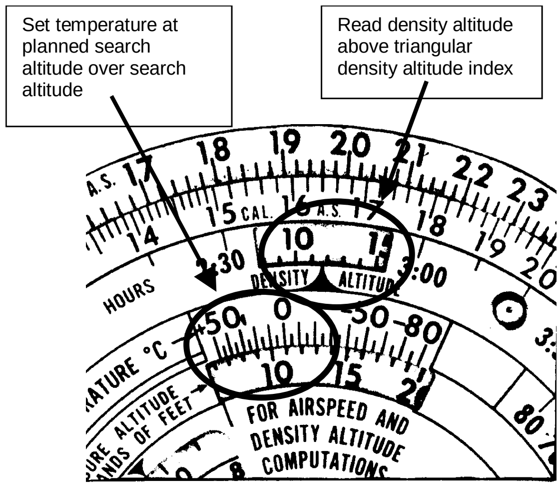


Figure 7-2

Convert the 80º F to Celsius (27º). Position +27 on the "Air Temperature ºC" scale over the pressure altitude of '3' (the pressure altitude scale is in thousands of feet). Read the number ('5') in the "Density Altitude" window (5 x 1,000' = 5,000').

7.2 Aircraft performance limitations

The combined effects of high altitude and temperature (high density altitude) can have a significant effect on performance of aircraft engines, wings, propellers, and the pilot and crew. If all missions were conducted on cool, low humidity days along the Gulf coast there would be no concern with air density and its implications on flight safety. Obviously, this isn't the case. In fact, these conditions have often been primary factors in aircraft accidents, and may result in loss of the search aircraft, unless you pay careful attention.

The most noticeable effect of a decrease in pressure (increase in density altitude) due to an altitude increase becomes evident during *takeoff, climb, and landing*. The purpose of the takeoff run is to gain enough speed to generate lift from the passage of air over the wings. If the air is thin, more speed is required to obtain enough lift for takeoff: hence, a longer ground run. An airplane that requires a 1,000' run for takeoff at a sea-level airport will require a run almost twice as long at an airport that is approximately 7,000' above sea level.

Elevation	Temperature	Engine Horsepower	Rate of Climb (ROC)	Take Off Distance
Sea Level	59°F	160	700 feet/minute	1,627 feet
	85°F	-	-	1,810 feet
7,000'	59°F	140	338 feet/ minute	3,627 feet
	85°F	-	-	4,200 feet

Compiled from aircraft flight manual. Presented here for training purposes only.

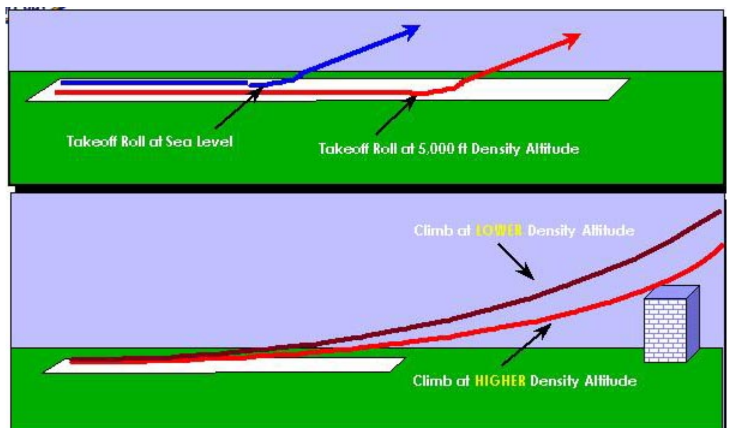


Figure 7-3

It is also true that the engine is less efficient in thin air, and the thrust of the propeller is less effective. The rate of climb is also slower at the higher elevation, requiring a greater distance to gain the altitude to clear any obstructions. In landing, the difference is not so noticeable except that the plane has greater groundspeed when it touches the ground.

Most search airplanes can operate at speeds of approximately 120 knots, or 2 miles per minute. A rate-of-climb of 100 feet per minute at 120 knots gives a no-wind climb angle or gradient of approximately 50 feet per mile, *substantially less* than that required to climb over rapidly rising, mountainous terrain. See the table below for examples at various weights (C172, 160 hp; gross weight is 2,400 lbs.).

PRESSURE ALTITUDE 4,000 FEET			
Temperature	Density Altitude, Feet	ROC @ 2,100 Pounds	ROC @ 2,400 Pounds
10ºF	1,600	820	630
60ºF	5,000	650	470
100ºF	7,500	540	370
PRESSURE ALTITUDE 6,000 FEET			
Temperature	Density Altitude, Feet	ROC @ 2,100 Pounds	ROC @ 2,400 Pounds
10ºF	4,000	700	520
60ºF	7,500	540	370
100ºF	10,000	410	260
PRESSURE ALTITUDE 10,000 FEET			
Temperature	Density Altitude, Feet	ROC @ 2,100 Pounds	ROC @ 2,400 Pounds
10ºF	9,000	460	300
60ºF	12,400	315	160
100ºF	15,000	200	50

Figure 7-4

Compared to turns at low altitude, turns in high density altitudes have larger turn radiuses and slower turn rates. The airplane cannot reverse course so quickly and a 180° turn requires more room. Steep-banked, tight turns should also be avoided because the aircraft may have insufficient power or speed (or both) to complete the turn without losing altitude.

Density altitude's effect on twin-engine aircraft can be catastrophic in the event of a power loss by one engine. Most would not be able to climb at all and may not be able to maintain level flight under such circumstances. The pilot then flies an airspeed that allows a minimum rate of descent and starts looking for a suitable place to land. Hopefully, a runway will be nearby.

7.2.1 Strategies

The mission staff can make a number of decisions to help minimize the effects of high density altitude operations and thus maximize flight safety. If aircraft having turbo-charged or super-charged engines are available, the incident commander may assign their crews that part of the search over the high terrain. Supercharging or turbo-charging regains some of the engine performance lost with the decrease in air density, but cannot improve upon that lost from the wings or propeller.

Incident commanders may schedule flights to avoid searching areas of high elevation during the hottest times of the day. This is a tradeoff though, in that the best sun angles for good visibility often coincide with the hot times of the day. The incident commander may also elect to limit crew size to minimize airplane total weight. Instead of dispatching a four-seat aircraft with a pilot, observer, and two scanners aboard, he may elect to send a pilot, observer and single scanner only. Again, this represents a tradeoff, where some search capability is sacrificed for a higher margin of safety.

The pilot may decide to takeoff on a mission with only the fuel required for that mission and the required reserve, rather than departing with full fuel tanks. Each crewmember can help by leaving all *nonessential* equipment or personal possessions behind. In high density altitudes, airplane performance can be improved significantly by simply leaving nonessential, excess weight behind.

To help remember these conditions and their effects, an observer should remember the four "H's." *Higher Humidity, Heat, or Height all result in reduced aircraft performance*. Available engine power is reduced, climb capability is reduced, and takeoff and landing distances are increased.

7.3 Effects on crewmember performance

The factors previously discussed can have similarly degrading effects on the ability of each crewmember to perform his or her job tasks. As air temperature increases, so does each crewmember's susceptibility to nausea, airsickness, and dehydration. As humidity increases with temperature, the body's ability to regulate its own temperature by perspiration can be negatively affected also, beginning the initial symptoms of heat exhaustion.

When operating in high temperatures, crewmembers should make every effort to drink plenty of water, juice, or caffeine-free soft drinks prior to, during, and after each mission to help prevent dehydration. Even though an individual may not be physically active, body water is continuously expired from the lungs and through the skin. This physiological phenomenon is called insensible perspiration or insensible loss of water.

The loss of water through the skin, lungs, and kidneys never ceases. Water loss is increased in flight because of the relatively lowered humidity at altitude, particularly on extended flights. Combating the loss of water during flights requires frequent water intake.

Typical dehydration conditions are: dryness of the tissues and resulting irritation of the eyes, nose, and throat, and fatigue relating to the state of acidosis (reduced alkalinity of the blood and body tissues). A person reporting for a flight in a dehydrated state will more readily notice these symptoms until fluids are adequately replaced.

Consumption of coffee, tea, cola, and cocoa should be minimized since these drinks contain caffeine. In addition, tea contains a related drug (theophyline), while cocoa (and chocolate) contain theobromine, of the same drug group. These drugs, besides having a diuretic effect, have a marked stimulating effect and can cause an increase in pulse rate, elevation of blood pressure, stimulation of digestive fluid formation, and irritability of the gastrointestinal tract.

Increasing the flow of outside air through the aircraft interior by the use of vents, or opening windows or hatches can usually remedy heat-related problems. If sufficient airflow cannot be gained, cooler air can usually be located by climbing the aircraft to a higher altitude. This may be inconsistent with search altitudes assigned by the incident commander or may be beyond the performance capability of the aircraft.

Altitude has several affects on human performance including ear block, sinus block and hypoxia. Observers should be aware of these factors in their own performance and also watch for them to occur in other crewmembers.

7.3.1 Ear block

As the aircraft cabin pressure decreases during ascent, the expanding air in the middle ear pushes the Eustachian tube open and, by escaping down it to the nasal passages, equalizes in pressure with the cabin pressure. But during descent, the pilot must periodically open the Eustachian tube to equalize pressure. This can be accomplished by swallowing, yawning, tensing muscles in the throat or, if these do not work, by the combination of closing the mouth, pinching the nose closed and attempting to blow through the nostrils (valsalva maneuver).

Either an upper respiratory infection, such as a cold or sore throat, or a nasal allergic condition can produce enough congestion around the Eustachian tube to make equalization difficult. Consequently, the difference in pressure between the middle ear and aircraft cabin can build up to a level that will hold the Eustachian tube closed, making equalization difficult if not impossible. This problem is commonly referred to as an "ear block."

An ear block produces severe ear pain and loss of hearing that can last from several hours to several days. Rupture of the eardrum can occur in flight or after landing. Fluid can accumulate in the middle ear and become infected. An ear block is prevented by not flying with an upper respiratory infection or nasal allergic condition. Adequate protection is usually not provided by decongestant sprays or drops to reduce congestion around the Eustachian tube. Oral decongestants have side effects that can significantly impair pilot performance. If an ear block does not clear shortly after landing, a physician should be consulted.

7.3.2 Sinus block

During ascent and descent, air pressure in the sinuses equalizes with the aircraft cabin pressure through small openings that connect the sinuses to the nasal passages. Either an upper respiratory infection, such as a cold or sinusitis, or a nasal allergic condition can produce enough congestion around the opening to slow equalization and, as the difference in pressure between the sinus and cabin mounts, eventually plug the opening. This "sinus block" occurs most frequently during descent.

A sinus block can occur in the frontal sinuses, located above each eyebrow, or in the maxillary sinuses, located in each upper cheek. It will usually produce excruciating pain over the sinus area. A maxillary sinus block can also make the upper teeth ache. Bloody mucus may discharge from the nasal passages.

A sinus block is prevented by not flying with an upper respiratory infection or nasal allergic condition. Adequate protection is usually not provided by decongestant sprays or drops to reduce congestion around the sinus openings. Oral decongestants have side effects that can impair pilot performance. If a sinus block does not clear shortly after landing, a physician should be consulted.

7.3.3 Hypoxia

Hypoxia is a state of oxygen deficiency in the body sufficient to impair functions of the brain and other organs. Hypoxia from exposure to altitude is due only to the reduced barometric pressures encountered at altitude, for the concentration of oxygen in the atmosphere remains about 21 percent from the ground out to space. The body has no built-in warning system against hypoxia.

Although deterioration in night vision occurs at a cabin pressure altitude as low as 5,000 feet, other significant effects of altitude hypoxia usually do not occur in the normal healthy pilot below 12,000 feet. From 12,000 to 15,000 feet of altitude, judgment, memory, alertness, coordination and ability to make calculations are impaired. Headache, drowsiness, dizziness and either a sense of euphoria or belligerence may also occur. In fact, pilot performance can seriously deteriorate within 15 minutes at 15,000 feet.

At cabin-pressure altitudes above 15,000 feet, the periphery of the visual field grays out to a point where only central vision remains (tunnel vision). A blue coloration (cyanosis) of the fingernails and lips develops. The ability to take corrective and protective action is lost in 20 to 30 minutes at 18,000 feet and 5 to 12 minutes at 20,000 feet, followed soon thereafter by unconsciousness.

The altitude at which significant effects of hypoxia occur can be lowered by a number of factors. Carbon monoxide inhaled in smoking or from exhaust fumes lowers hemoglobin (anemia), and certain medications can reduce the oxygen-carrying capacity of the blood to the degree that the amount of oxygen provided to body tissues will already be equivalent to the oxygen provided to the tissues when exposed to a cabin pressure altitude of several thousand feet. Small amounts of alcohol and low doses of certain drugs, such as antihistamines, tranquilizers, sedatives and analgesics can, through their depressant actions, render the brain much more susceptible to hypoxia. Extreme heat or cold, fever, and anxiety can increase the body's demand for oxygen, and hence its susceptibility to hypoxia.

Hypoxia can be prevented by: heeding factors that reduce tolerance to altitude, by enriching the inspired air with oxygen from an appropriate oxygen system and by maintaining a comfortable, safe cabin pressure altitude. For optimum protection, pilots are encouraged to use supplemental oxygen above 10,000 feet during the day, and above 5,000 feet at night. The Federal Aviation Regulations require that the minimum flight crew be provided with and use supplemental oxygen after 30 minutes of exposure to cabin pressure altitudes between 12,500 and 14,000 feet, and immediately on exposure to cabin pressure altitudes above 14,000 feet. Every occupant of the aircraft must be provided with supplement oxygen at cabin pressure altitudes above 15,000 feet.

7.4 Mountainous terrain

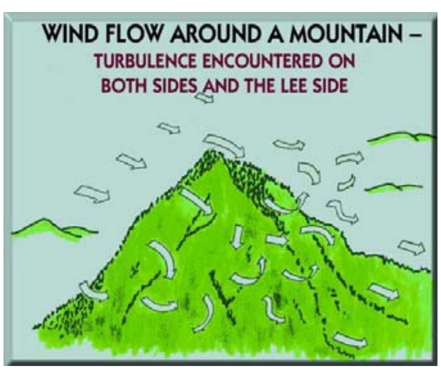
Flying in mountainous terrain requires special training that is beyond the scope of this course. Aircrews flying the mountains must complete a course such as *Mountain Fury*.

Briefly, when flying in mountainous areas it is recommended that flights be planned for early morning or late afternoon because heavy turbulence is often encountered in the afternoon, especially during summer. In addition, flying at the coolest part of the day reduces density altitude. Attempt to fly with as little weight as possible, but don't sacrifice fuel; in the event of adverse weather, the additional reserve could be a lifesaver.

Study sectionals for altitudes required over the route and for obvious checkpoints. Prominent peaks make excellent checkpoints, as do rivers and passes. Be aware that mountain ranges have many peaks that may look the same to the untrained eye, so continually crosscheck your position with other landmarks and radio aids if possible. Also, the minimum altitude at which many radio aids are usable will be higher in the mountains. For that reason, low-frequency navigation, such as ADF, LORAN, or GPS tend to work best in the mountains.

Crews must be constantly careful that the search never takes them over terrain that rises faster than the airplane can climb. Narrow valleys or canyons that have rising floors must be avoided, unless the aircraft can be flown from the end of higher elevation to the lower end, or the pilot is *certain* that the aircraft can climb faster than the terrain rises. Careful chart study by the crew prior to flight will help identify this dangerous terrain.

A weather check is essential for mountain flying. Ask specifically about winds aloft even when the weather is good. Expect winds above 10,000 feet to be prevailing Westerlies in the mountain states. If winds aloft at your proposed altitude are above 30 knots, do not fly. Winds will be of much greater velocity in passes, and it will be more turbulent as well. Do not fly closer than necessary to terrain such as cliffs or rugged areas. Dangerous turbulence may be expected, especially when there are high winds.



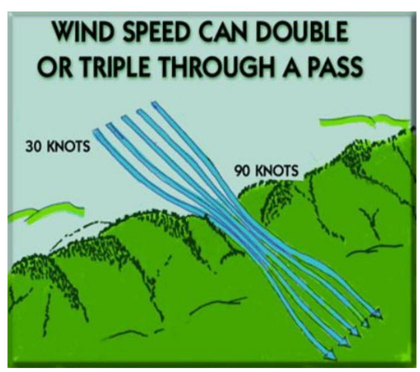


Figure 7-5

Chapter

8

8. Navigation and Position Determination

Navigation is the process of continuously determining your position so you can get from one place to a desired location. By correctly using various navigational techniques, you can efficiently proceed from one point to the next while keeping off-course maneuvering, elapsed time, and fuel consumption to a minimum. Position determination (situational awareness) enables the crew to accurately determine and report position, respond quickly to changes and emergencies, locate targets, and record and report sightings. This chapter will cover the basic tools of navigation, navigational techniques, and the use of radio aids and instruments for navigation and position determination.

OBJECTIVES:

1. Define the following navigational terms:
   a. Course, heading and ground track.
   b. Drift and drift correction.
   c. Nautical mile and knot.
   d. Latitude and longitude.
2. Given a map or sectional: identify an object given its latitude and longitude; and given a position determine its latitude and longitude.
3. Discuss considerations for operating near controlled airports, and identify them on a sectional.
4. Discuss the following special use airspaces, and identify them on a sectional:
   a. Prohibited and restricted areas.
   b. Military operating areas and training routes.
5. Discuss the uses and limitations of the following NAVAID's:
   a. ADF
   b. VOR
   c. DME
   d. GPS

6. Given a sectional chart, locate and discuss the following:
    a. Physical features such as topographical details.
    b. Towns and cities.
    c. Highways and roads
    d. Towers; determine height both in MSL and AGL.
    e. Airways and radio aids to navigation.
    f. Airports and airport data.
7. Given a sectional chart, discuss the information found in the legend.
8. Given a sectional chart, locate Maximum Elevation Figures and state their meaning.
9. Given a sectional chart, a plotter, and two points on the chart:
    a. Determine the heading.
    b. Determine the distance between the points (nautical and statute miles).
10. Given a sectional chart, a plotter, and two airports:
    a. Plot the course.
    b. Identify check points along the route.
    c. Calculate how long it should take to get from one airport to the other, flying at 100 knots and no wind.
11. Given data from NAVAID's, track the current position of an aircraft and determine the position of a ground feature (sectional and map).
12. State the size of a full and a one-quarter standardized grid.
13. Given Attachment E of the *U.S. National SAR Supplement to the International Aeronautical and Maritime SAR Manual*, grid a sectional.
14. Given coordinates and a sectional, use the *Standardized Latitude and Longitude Grid System* to draw a search grid.

8.1 Navigation Terms

In order to effectively communicate with the pilot and ground teams, the scanner and observer must have a clear understanding of various terms that are used frequently when flying aboard search aircraft. These are not peculiar to search and rescue, but are used by all civilian and military aviators.

Course - The planned or actual path of the aircraft over the ground. The course can be either *true course* or *magnetic course* depending upon whether it is measured by referencing true north or magnetic north. The magnetic north pole is *not* located at the true North Pole on the actual axis of rotation, so there is usually a difference between true course and magnetic course.

Pilots measure true course against a meridian of longitude at the midpoint of each leg, and all of these meridians point to the true North Pole. However, since the aircraft compass can only point at the magnetic north pole you must apply *magnetic variation* to the true course to determine the magnetic direction you must fly in order to follow the true course. East magnetic variation is subtracted from measured true courses and west variation is added.

You can find magnetic variation factors in several places, and you will learn more about this in the section concerning charts. Magnetic variation factors also take into account abnormalities in the earth's magnetic field due to the uneven distribution of iron ore and other minerals.

Heading - The direction the aircraft is *physically* pointed. An airplane's track over the ground doesn't always correspond with the direction they're pointed. This is due to the effect of wind. True heading is based on the true North Pole, and magnetic heading is based on the magnetic north pole. Most airplane compasses can only reference magnetic north without resorting to advanced techniques or equipment, so headings are almost always magnetic.

Drift, or Drift Effect - The effect the wind has on an aircraft. The air mass an aircraft flies through rarely stands still. If you try to cross a river in a boat by pointing the bow straight across the river and maintaining that heading all the way across, you will impact the river bank downstream of your initial aim point due to the effect of the river current. In an aircraft, any wind that is not from directly in the front or rear of the aircraft has a similar affect. The motion of the airplane relative to the surface of the earth depends upon the fact that the airplane is moving relative to the air mass and the air mass is moving relative to the surface of the earth. Adding these two gives the resultant vector of the airplane moving relative to the surface of the earth. The angle between the heading and the actual ground track is called the drift angle.

Drift Correction - A number of degrees added to or subtracted from the aircraft heading intended to negate drift or drift effect. In the rowboat example, if you had aimed at a point upstream of the intended destination, you would have crossed in a straighter line. The angle between the intended impact point and the upstream aim point is analogous to drift correction.

Ground Track - The actual path of the airplane over the surface of the earth.

Nautical mile *(nm) -* Distances in air navigation are usually measured in *nautical miles,* not statute miles. A nautical mile is about 6076 feet (sometimes rounded to 6080 feet), compared to 5280 feet for the statute mile. Most experienced aviators simply refer to a nautical mile as a mile. *Aircrews should remain aware of this difference when communicating with ground search teams because most ground or surface distances are measured using statute miles or kilometers*. To convert nautical miles into statute miles, multiply nautical miles by 1.15. To find kilometers, multiply nautical miles by 1.85. Also, one nautical mile is equal to one minute of latitude: this provides a convenient scale for measuring distances on any chart. Nautical miles are abbreviated "nm".

Knots (kts) - The number of nautical miles flown in one hour. Almost all airspeed indicators measure speed in terms of knots, not miles per hour. One hundred knots indicates that the aircraft would fly one hundred nautical miles in one hour in a no wind condition. Some aircraft have airspeed indicators that measure speed in statute miles per hour, and the observer should be alert to this when planning. Knots can be used to measure both *airspeed* and *ground speed*. The air mass rarely stands still, and any headwind or tailwind will result in a difference between the aircraft's airspeed and ground speed. If you fly eastward at 100 knots airspeed, with the wind blowing from the west at 15 knots, your speed over the ground would be 115 knots. If you fly westbound into the wind, your speed over the ground drops to 85 knots.

8.2 Latitude and longitude

In order to successfully navigate any vessel, the navigator must first have an understanding of the basic tools of navigation. Navigation begins with is a common reference system or imaginary grid "drawn" on the earth's surface by *parallels of latitude* and *meridians of longitude.* This system is based on an assumption that the earth is spherical. In reality, it's slightly irregular, but the irregularities are small, and errors caused by the irregularities can be easily corrected. The numbers representing a position in terms of latitude and longitude are known as the coordinates of that position. Each is measured in degrees, and each degree is divided into 60 smaller increments called minutes. Each minute may be further divided into 60 seconds, or tenths and hundredths of minutes.

8.2.1 Latitude

Latitude is the angular distance of a place north or south from the equator. The equator is a great circle midway between the poles. Parallel with the equator are lines of latitude. Each of these parallel lines is a small circle, and each has a definitive location. The location of the latitude is determined by figuring the angle at the center of the earth between the latitude and the equator.

The equator is latitude 0º, and the poles are located at 90º latitude. Since there are two latitudes with the same number (two 45º latitudes, two 30º, etc.) the letter designators N and S are used to show which latitude is meant. The North Pole is 90º north of the equator and the South Pole is 90º south of the equator. Thus the areas between the poles and the equator are known as the northern and southern hemispheres.

8.2.2 Longitude

We have seen how the north-south measurement of positions is figured. With only latitude, it is still impossible to locate a point. This difficulty is resolved by use of longitude, which indicates east-west location.

There is no natural starting point for numbering longitude. Therefore the solution is to select an arbitrary starting point. When the sailors of England began to make charts, they chose the meridian through their principal observatory in Greenwich, England, as the zero line. Most countries of the world have now adopted this line. The Greenwich meridian is sometimes called the first, or prime meridian (actually, the zero meridian).

Longitude is counted east and west from this meridian through 180º. Thus the Greenwich Meridian is zero degrees longitude on one side of the earth, and after crossing the poles it becomes the 180th meridian (180º east or west of the 0-degree meridian). Therefore we have all longitudes designated either west or east, for example, E 140º or W 90º. The E and W designations define the eastern and western hemispheres.

8.2.3 Position location

Refer to Figure 8-1. *By convention, latitude is always stated first*.

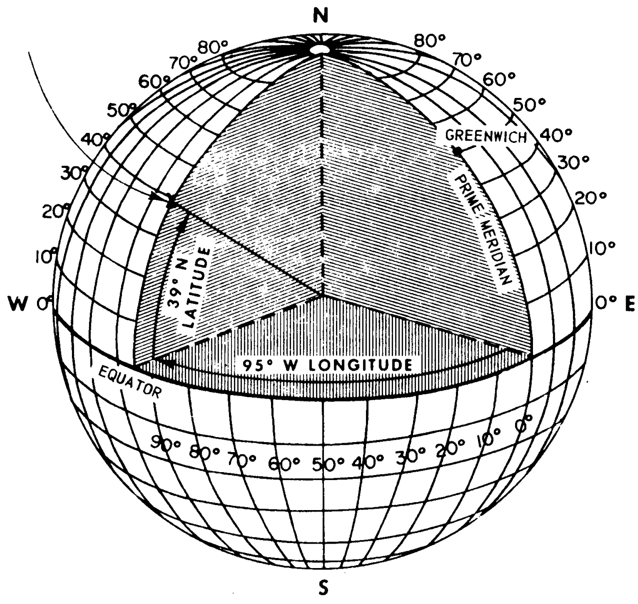


Figure 8-1

This system is used to precisely locate any point on the earth's surface. When identifying a location by its position within this latitude-longitude matrix, you identify the position's *coordinates,* always indicating latitude first and then longitude. For example, the coordinates N 39° 04.1', W 95° 37.3' are read as "north thirty-nine degrees, four point one minutes latitude, west ninety-five degrees, thirty-seven point three minutes longitude." If you locate these coordinates on *any* appropriate aeronautical chart of North America, you will *always* find Philip Billard Municipal Airport in Topeka, Kansas.

It is important to remember that in the northern hemisphere, latitude numbers increase as you proceed from south to north, and decrease as you move north to south. In the western hemisphere, longitude numbers increase when proceeding east to west, and decrease when moving west to east. Since the GPS receiver displays latitude and longitude with a great degree of accurately, pilots can use this tool to navigate and to fly very precise search patterns.

8.3 Magnetic variation

Variation is the angle between true north and magnetic north. It is expressed as east variation or west variation depending upon whether magnetic north (MN) is to the east or west of true north (TN), respectively. The north magnetic pole is located close to latitude N 71º, longitude W 96º - about 1,300 miles from the geographic or true north pole. If the earth were uniformly magnetized, the compass needle would point toward the magnetic pole, in which case the variation between true north and magnetic north could be measured at any intersection of the meridians.

Actually, the earth is not uniformly magnetized. In the United States the needle usually points in the general direction of the magnetic pole but it may vary in certain geographical localities by many degrees. Consequently, the National Ocean Survey has carefully determined the exact amount of variation at thousands of selected locations in the United States. The amount and the direction of variation, which change slightly from time to time, are shown on most aeronautical charts as broken red lines, called isogonic lines, which connect points of equal magnetic variation. The line connecting points at which there is no variation between true north and magnetic north is the agonic line.

8.4 Airspace

For traffic management purposes, the FAA has designated that all airspace within the United States falls into one of six different class designations (A, B, C, D, E, and G). Flight within each class requires certain communication, equipment, pilot experience, and, under some circumstances, weather requirements. Specific requirements for each class are complex, but they can be simplified somewhat with several broad generalizations.

Regardless of flight rules, the most stringent requirements normally are associated with flight in airspace immediately surrounding a major airport, due to the high density of operations conducted there. Observers must be alert for required communication when it appears a search will be conducted within 40 miles of a major airport or within 5 miles of any airport having an operating control tower. These are color coded *blue* on sectional charts. Major airports in this context are generally near major metropolitan areas and appear at or near the center of concentric blue-, magenta-, or gray-colored circles. Also, crew resource management and the "sterile cockpit" environment are essential in or near these busy airports in order to "see and avoid" obstacles and other aircraft.

When operating the aircraft under VFR, in most classes of airspace the pilot can change the direction of flight or aircraft altitude without any prior coordination with air traffic control. This will almost always be the case when weather allows visual search patterns below the bases of the clouds.

8.4.1 Special Use Airspace

Although not a class of airspace, the FAA has designated some airspace as "special use" airspace. The FAA has specifically created special use airspace for use by the military, although the FAA retains control. Active special use airspace can become a navigational obstacle to search aircraft and uncontrolled objects (e.g., missiles) within the airspace can present a serious threat to the safety of aircraft and personnel. Special use airspace normally appears on sectional charts as irregularly shaped areas outlined by *either blue or magenta hatched lines*. It is also identified by either a name, such as Tyndall E MOA, or an alphanumerical identifier like R-4404A.

Prohibited Areas contain airspace within which the flight of aircraft is prohibited for national security or other reasons. An example is the airspace around the White House.

In the first example, the letters MOA (Military Operations Area) indicate that the Tyndall E airspace is a military operating area. Within its boundaries, the military may be conducting high-speed jet combat training or practicing air-to-ground weapons attack, without objects actually being released from the aircraft. Figure 8-2 illustrates how the MOA is portrayed on the sectional chart. MOA boundaries and their names are always printed in *magenta* on the sectional chart.

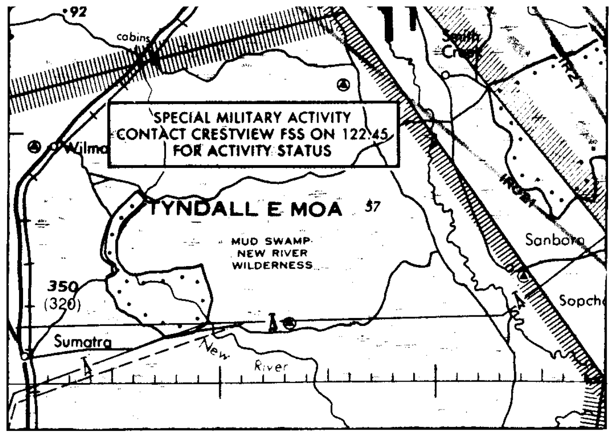


Figure 8-2

Civilian aircraft operating under VFR are *not* prohibited from entering an active MOA, and may do so at any time without any coordination whatsoever (although this is considered foolish by many pilots). As stated earlier, since the FAA retains control of the airspace, it is prudent to contact the controlling air traffic facility before continuing a search into any MOA.

Military aircraft, often flying at very low altitudes and at high speeds, are usually not in radar or radio contact with the air traffic controller (nor can they see or hear you). A controller can only provide positive separation to civilian IFR aircraft from the MOA boundary, *not* from the military aircraft itself. This may force significant maneuvering off your intended course.

In the second example, the “R” prefix to the five-letter identifier indicates this is a *Restricted Area*. The Army may be conducting artillery firing within this airspace, or military aircraft may be practicing actual air-to-surface bombing, gunnery, or munitions testing. Shells, bombs, and bullets, as well as the dirt and fragments they throw into the air on ground impact, present a severe hazard to any aircraft that might come in their path. Figure 8-3 illustrates how a typical restricted area is portrayed on the sectional chart. The restricted area’s boundaries are always printed in *blue*.

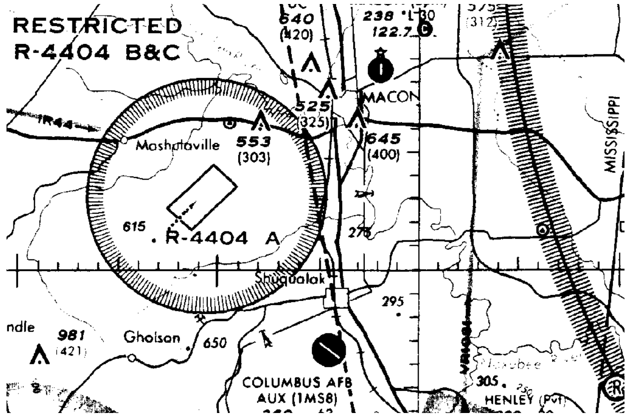


Figure 8-3

Warning Areas are similar to restricted areas, except that they are beyond the three-mile limit from the U.S. coastline and are therefore in international airspace. Alert Areas show airspace within which there may be a lot of pilot training or unusual aerial activity.

Hours of use and vertical limits of special use airspace areas, as well as the FAA facility controlling each area, are printed in one of the margins of the sectional chart. If the crew has any doubt about entering special use airspace, it should contact the appropriate air traffic control facility first to check the status of the area in question.

8.4.2 Military Training Routes

Although not classified by the FAA as special use airspace, military training routes (MTRs) are for military low-altitude high-speed training. An understanding of each type of training route, and the manner in which an active route can affect other traffic, will help the aircrew accomplish their intended mission.

Military training routes that may be used by high-speed jet aircraft are identified by one of two designations, depending upon the flight rules under which the military operates when working within that airspace. *Instrument Routes* (IR) and *Visual Routes* (VR) are identified on sectional aeronautical charts by medium-weight solid gray lines with an alphanumeric designation. 4-digit numbers identify MTRs flown at or below 1500 feet AGL; 3-digit numbers identify those flown above 1500 feet AGL. In Figure 8-4 there are two such examples east of the Clarksville Airport symbol -- IR-120, and VR-1102.

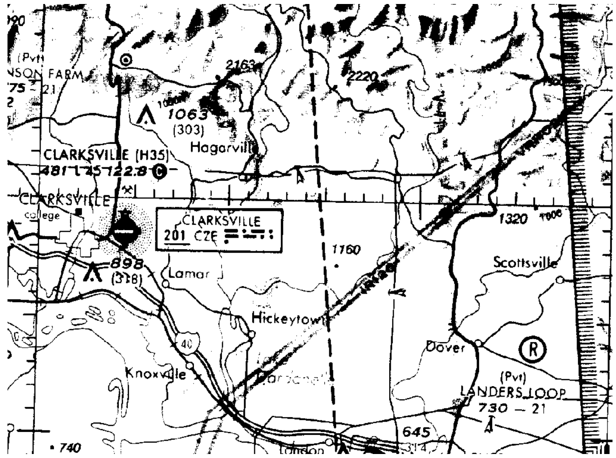


Figure 8-4

Only route centerlines are printed on sectional charts, but each route includes a specified lateral distance to either side of the printed centerline and a specific altitude "block". Route widths vary, but can be determined for any individual route by requesting Department of Defense *Flight Information Publication AP-1B* at the Flight Service Station.

The letters *IR* in IR-120 indicate that military aircraft operate in that route according to IFR clearances issued by air traffic control. Other non-military VFR aircraft may enter the lateral or vertical boundaries of an active IR route without prior coordination, while aircraft operating IFR are kept out by air traffic control. Just as in the case of a MOA, air traffic control may not have radar and radio contact with the military aircraft using the route. Therefore, it is necessary to provide separation between other IFR aircraft and the route airspace regardless of where the military aircraft may be located along the route. This may force either a route or altitude change. WASAR members can request the status of IR routes from the controlling air traffic facility.

The letters *VR* in VR-1102 indicate that the military operates under VFR when operating within the lateral and vertical limits of that airspace. The see-and-avoid concept applies to *all* civilian and military aircraft operating there, and all crew members must be vigilant in visual lookout when within or near a VR training route. Many military missions go to and from visual training routes' start and exit points on IFR clearances, and the prudent crew can inquire about the status of the route with air traffic control when operating through or near a VR training route.

You can determine *scheduled* military activity for restricted areas, MOAs, and military training routes by checking *Notices to Airmen* (NOTAMS) at the Flight Service Station. However, checking with the air traffic control facilities is preferable, since it will reveal *actual,* "real time" activity versus *scheduled* activity. When flying through any special use airspace or training route, crewmembers should be alert and cautious at all times, because incorrect or incomplete coordination between the military and the FAA is the rule rather than the exception.

8.5 Electronic Aids to Navigation (NAVAID's)

From the standpoint of a mission aircrew, navigational instruments are the means to an end. Navigational equipment allows the aircraft to be flown to a desired location, such as a search pattern entry point, with precision and economy. Once in the search or assessment area, this equipment allows the pilot to fly the assigned area precisely and thoroughly. NAVAID's also enable the crew to track their position and record sightings. From the mission staff's viewpoint, proper use of this equipment assures them that the assigned area was actually flown -- the only variables left to accommodate are search effectiveness and the inherent limitations of scanning.

This section will cover some of the electronic means available that can help in navigating. These systems not only can help you determine your position in reduced visibility or over desolate terrain, but can help you more accurately fly search and assessment patterns and report your observations to ground personnel or to mission base.

One drawback to all of this sophisticated equipment is that they may distract the pilot (and observer) from looking outside of the aircraft. The best way to avoid this trap is to become and continue to be very familiar with the operation of this equipment. Training and practice (along with checklists or aids) allows each crewmember to set or adjust instruments with minimum fuss and bother, thus allowing them to return their gaze outside the aircraft where it belongs. All members of the aircrew should be continuously aware of this trap.

Additionally, it is important that observers use this equipment to help the pilot maintain situational awareness. The aircrew should always know the aircraft's position on the sectional chart, and these instruments enable them to do so with great accuracy.

8.5.1 Automatic Direction Finder (ADF)

The automatic radio compass, generally known as the Automatic Direction Finder (ADF), is used to receive radio guidance from stations such as four-course ranges, radio beacons, and commercial broadcast facilities. The automatic direction finder indicates the direction of the station being received. This direction is shown in relation to the heading of the aircraft. The ADF is the least accurate of all the navigational instruments.

Probably the most common use of the automatic direction finder is in "homing". The pilot tunes in a desired station, and then flies directly to that station by keeping the ADF indicating needle on the zero mark. When the needle points to the zero mark, the aircraft is headed toward the station. When the station is passed, the needle will swing around to the 180-degree position, indicating that the station is behind.

The ADF has three primary components -- a transmitter on the ground, a receiver and an indicator, both in the aircraft. Transmitters include non-directional radio beacons (NDBs) and commercial AM radio stations. Each transmitter emits a single signal on a specific frequency in all directions. ADF equipment aboard the aircraft indicates the *relative* bearing of the station, or its relative direction from the aircraft. In Figure 8-5, the airplane is shown flying north, or flying both a heading and a course of 000°. The ADF "indicator" illustrated shows the direction to the transmitter is 30º to the right of the plane's nose. In the illustration only 0, 090, 180, and 270 are shown on the indicator, and that is true of many ADF indicators. You may have to interpret index marks between these major bearings to determine the exact bearing to the station.

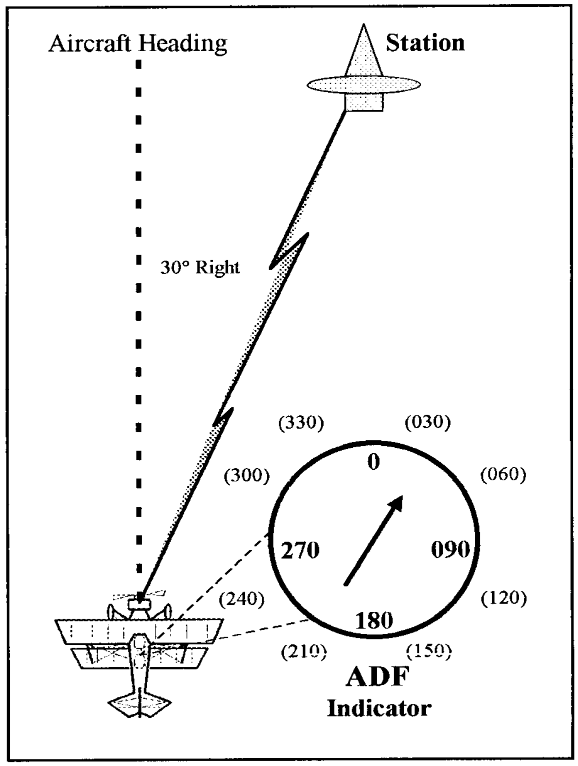


Figure 8-5

If you turn the aircraft 30º to the right (heading 030), the plane will point directly at the station, and the pointer will now point at 0º relative bearing. In a no-wind condition, if you maintained that 030 heading and the pointer at 0º relative bearing, you would fly directly to that transmitter (Figure 8-6).

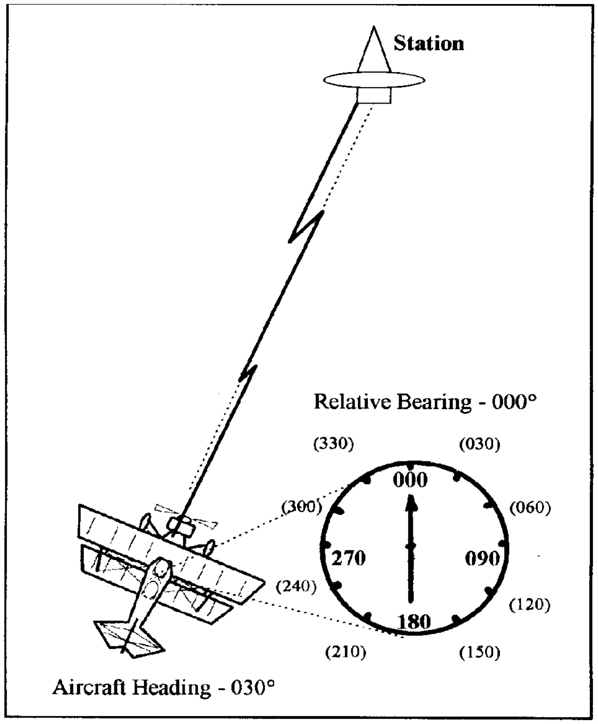


Figure 8-6

In a crosswind, the pilot estimates the airplane's drift, and computes a drift correction factor to be added to or subtracted from the aircraft heading. If he estimates 5º of drift to the right, his drift correction will be to subtract 5º from the airplane's heading, and turn the aircraft 5º to the left. The aircraft would thus have a heading of 025, its course over the ground would remain 030, and the ADF would show a relative bearing of 005, or 5º to the right. In the rowboat-crossing-the-river analogy, the boat's bow points upstream, but due to the current, it travels in a straight line across the river. The aim point is slightly to the right of the bow as the boat proceeds across.

All ADF stations transmit an audible identifier that you must identify before using the signal for navigation. All ADFs are highly susceptible to interference when thunderstorms are in the general vicinity, and their transmissions are restricted to line-of-sight only. Signals can also be blocked by terrain or other obstructions, especially when the aircraft is operating at low altitudes.

8.5.2 Very High Frequency Omni-directional Range (VOR)

The very high frequency omni-directional range (VOR) radio navigation system operates on a specific frequency in the VHF range of 109.0 to 117.9 megahertz and transmits 360 directional radio beams or *radials* that, if visible, would resemble the spokes radiating from the hub of a bicycle wheel. Each station is aligned to magnetic north so that the 000 radial points from the station to magnetic north. Every other radial is identified by the magnetic direction to which it points *from* the station, allowing the pilot to navigate directly to or from the station by tracking along the proper radial. The VOR is an accurate and reliable navigational system, and is the current basis for all instrument flight in the U.S.

Like the ADF, the main components are in three pieces: the ground transmitter, the receiver, and the indicator. Controls on the receiver are covered in the Nav/Comm section of Aircraft Instruments.

To help light plane pilots plan and chose routes, the FAA has developed the Victor airway system, a “highway” system in the sky that uses specific courses to and from selected VORs. When tracing the route of a missing aircraft, search airplanes may initially fly the same route as the missing plane, so it is very important you know the proper procedures for tracking VOR radials.

Figure 8-7 shows a VOR indicator and the components that give the information needed to navigate, including a vertical pointer, OFF/TO-FROM flag or window, and a course-select knob. The vertical pointer, also called a course deviation indicator (CDI) is a vertically mounted needle that swings left or right showing the airplane's location in relation to the course selected beneath the course pointer. The OFF/TO-FROM indicator shows whether the course selected will take the airplane to or from the station. When it shows “OFF”, the receiver is either not turned on or it’s not receiving signals on the selected frequency. The course selector knob is used to select the desired course to fly either toward or away from the station.

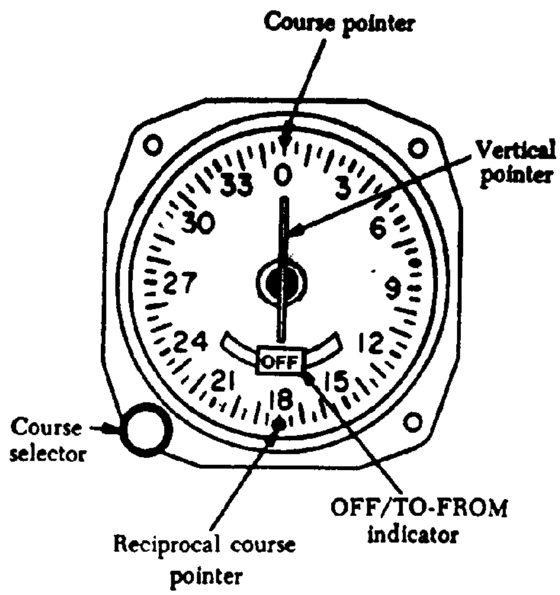


Figure 8-7

Flying to the VOR station is simple. Find the station’s frequency and its Morse code audio identifier using the sectional chart. Next, tune the receiver to the correct frequency and identify the station by listening to its Morse code. If you can’t positively identify the station, you should not use it for navigation.

After identifying the station, slowly turn the course selector knob until the TO-FROM indicator shows TO and the CDI needle is centered. If you look at the course that's selected beneath the course pointer at the top of the indicator, you’ll see the course that will take you directly to the station. The pilot turns the aircraft to match the airplane's heading with that course and corrects for any known winds by adding or subtracting a drift correction factor. The pilot keeps the CDI centered by using very small heading corrections and flies the aircraft directly to the station. When the aircraft passes over the station, the TO-FROM indicator will flip from TO to FROM.

To fly away from a station, tune and identify the VOR, then slowly rotate the course select knob until the CDI is centered with a FROM indication in the window. Look at the selected course, again normally at the top of the indicator, to determine the outbound course. The pilot turns the aircraft to that heading, corrects for wind drift, and keeps the CDI needle in the center to fly directly away from the station.

Figure 8-8 shows a hypothetical VOR with the 0° inbound and outbound courses simulating a Victor airway. In order to fly that airway, set 0° beneath the course pointer and determine the aircraft's position relative to the selected course. Each airplane has the 0° course selected under its course pointer, but the top airplane has a "FROM" indication. This indicates that the plane is north of the station. The vertical pointer's right deflection indicates that the desired 0° course from the station is off to the right. Since the plane is flying about a 330° heading, the pilot would turn back to the right to join the 0° course outbound from the station.

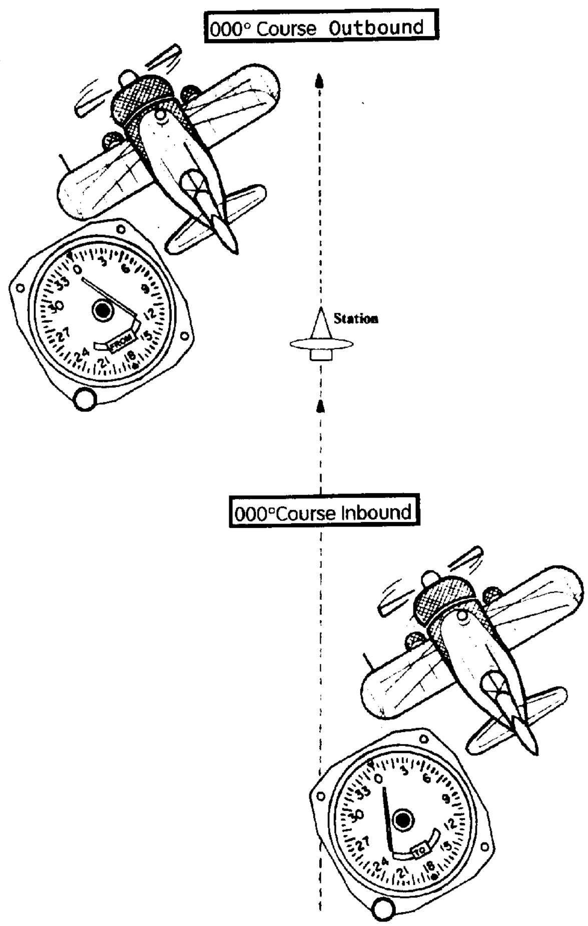


Figure 8-8

The indicator in the airplane southeast of the station has a "TO" indication, which, with the 0° course selected indicates it's south of the station. The pointer's left deflection indicates the 0° course to the station is to the plane's left. Since this plane also is heading 330°, it does not need to turn farther to *intercept* the 0° course to the station.

The display in the north plane would show the same indication if it were heading 360° or 030°, since in any case the 0° course from the station is still to the right. Likewise, the south plane would have the same indications regardless of the direction it's pointed. At any given point in space, the VOR display always gives the same indication *regardless* of the direction the airplane is pointing.

VOR can be used like ADF to determine a position in relation to a selected station, and the process is considerably simpler due to the directional nature of the VOR's signals. Rotate the course select knob slowly until the CDI is centered with a FROM indication, and look beneath the reciprocal course pointer for the radial. You can draw that radial as a line of position from the station's symbol on the sectional chart. Even better, if you can receive two stations you can establish position with very good accuracy by drawing the two radials: where they cross is where you are (this is often referred to as a "cross-radial").

Each VOR station on the chart has a surrounding compass ring already oriented towards magnetic north. Therefore, it isn't necessary to correct for magnetic variation. The use of the printed compass circle surrounding the station on the chart eliminates the need for using the plotter's protractor as well. Use any straight edge to draw the radial by connecting the station symbol with a pencil line through the appropriate radial along the circle. The radial drawn on the chart shows direction, but does not indicate distance from the station. But, you can get an accurate position "fix" by repeating the procedure with another VOR.

Using VOR has several advantages over using ADF. The directional nature of the VOR transmissions makes them easier to use for navigation than the non-directional signal from a NDB. Signals from VOR's are also much less susceptible to interference from thunderstorms and static electricity produced by weather phenomena. The directional signals from VOR's also make it much easier to correct for crosswinds. Like ADF, VOR is limited by signal blockage from high terrain and obstructions or during flight at very low altitudes. Finally, if the VOR equipment has failed you will know it.

In order to use a VOR for instrument flight, the receiver must be functionally checked every thirty days (or prior to any instrument flight). This check must be performed by an instrument rated pilot and logged in the aircraft's flight logbook.

8.5.3 Distance Measuring Equipment (DME)

Finding bearing or direction to a station solves only one piece of the navigation puzzle. Knowing the distance to the station is the final piece to the puzzle that allows fliers to navigate more precisely. You can use the cross-radial method discussed previously to obtain your distance from the stations, but an even easier method is provided by distance measuring equipment (DME).

DME continuously measures the distance of the aircraft from a DME ground unit that is usually co-located with the VOR transmitter (then called a VORTAC). The system consists of a ground-based receiver/transmitter combination called a transponder, and an airborne component called an interrogator. The interrogator emits a pulse or signal, which is received by the ground-based transponder. The transponder then transmits a reply signal to the interrogator. The aircraft's DME equipment measures the elapsed time between the transmission of the interrogator's signal and the reception of the transponder's reply and converts that time measurement into a distance.

This measurement is the actual, straight-line distance from the ground unit to the aircraft, and is called *slant range* (Figure 8-9). This distance is continuously displayed, typically in miles and tenths of miles, on a dial or digital indicator on the instrument panel. When DME is used in combination with VOR, a pilot can tell at a glance the direction and distance to a tuned station.

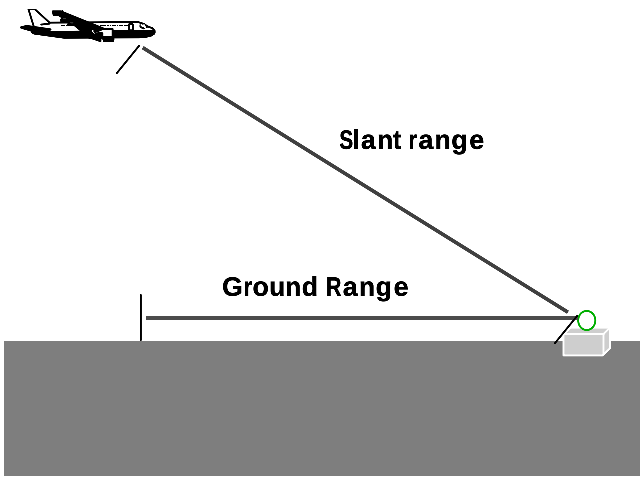


Figure 8-9

DME measures straight-line distance, or slant range, so *there is always an altitude component within the displayed distance*. If you fly toward a station at an altitude of 6,000 feet over the station elevation, the DME will never read zero. It will continuously decrease until it stops at one mile. That mile represents the aircraft's altitude above the station. The distance readout will then begin to increase on the other side of the station. Under most circumstances the altitude component of slant range can be ignored, but when reporting position using DME, especially to air traffic controllers, it is customary to report distances in "DME", not nautical miles, e.g., "Holly Springs 099° radial at 76 DME."

Some DME equipment can also compute and display the actual ground speed of the aircraft, provided that the aircraft is tracking *directly* to or from the ground station (and usually only after the aircraft has been stabilized on this track for one or two minutes). In all other circumstances, the ground speed information is not accurate and should be ignored.

8.5.4 LORAN

Long Range Navigation (LORAN) is a navigational system developed by the maritime community that utilizes low frequency radio stations to determine the aircraft position with, under most conditions, considerably greater accuracy than ADF, VOR, or DME. It operates in the 90 to 110 kHz frequency band and is based upon measurement of the difference in time of arrival of radio frequency energy pulses. These pulses are radiated by a chain of transmitters that are separated by hundreds of miles. Within a chain, one station is designated as the master station (M), and the other stations are designated as secondary stations. Signals transmitted from the secondary stations are synchronized with those from the master station. The measurement of a time difference (TD) is made by a receiver that compares a zero crossing of a specified radio-frequency cycle within the pulses received from the master and secondary stations of a chain. Loran provides predictable accuracy of 0.25 nautical miles or better, depending on the user's location within the signal coverage area in certain coastal regions of the chain.

LORAN systems, while having great utility, are vulnerable to certain system problems that can degrade their performance. Because the transmitters are ground-based, high terrain or obstructions between the transmitters and the receiver can block the signal. Ground interference can similarly affect signal reception at very low altitudes even over flat terrain, depending upon the receiver's distance from the chain stations. Signals are also vulnerable to interference from severe electrical storms. Frequently, when the receiver momentarily loses one or more of the stations, the displayed position stays at the last position prior to the signal loss. When the lost signal is acquired again, the calculations resume and the correct position will return. In the interim, however, the "stuck" position is not updating and can give the crew an erroneous indication. Crewmembers are also cautioned to check the instructions of the individual LORAN for the stored chain data. Ground station frequencies and time-delay intervals used within the chains in many cases cannot be “tuned” by the crew, having been permanently programmed by the manufacturer instead.

The FAA has not approved all LORAN receivers for use in instrument flight conditions. A small placard or label on the aircraft instrument panel will list the conditions for use. Unless you are *certain* the receiver and its installation are approved for operations in instrument conditions, LORAN should only be used in visual weather conditions.

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8.5.5 Global Positioning System (GPS)

Initially developed by the Department of Defense for military users, the Global Positioning System has become the most accurate navigational system available to civilian aircraft operators. Certified systems will eventually replace many of the navigational systems already discussed, as they already have replaced the ADF.

The system relies on a chain of 24 satellite transmitters in polar orbits about the earth. The speed and direction of each satellite, as well as each satellite's altitude is precisely maintained so that each satellite remains in a highly accurate and predictable path over the earth's surface at all times.

GPS receivers process signals transmitted by these satellites and triangulate the receiver's position, which the user again can read directly in latitude and longitude coordinates from a digital display. Similar additional features as those discussed in LORAN are available and vary depending upon the design and manufacturer. The system is substantially more accurate than LORAN, VOR, DME, or ADF and has several advantages.

Because the transmitters are satellite based, not ground based, and the signals are essentially transmitted *downward,* system accuracy is not significantly degraded in mountainous terrain. Additionally, the system is not normally vulnerable to interference from weather or electrical storms. Receivers can typically process as many as twelve received signals simultaneously, and can automatically deselect any satellite whose signal doesn't meet specific reception parameters. The system can function with reasonable accuracy using as few as three received signals.

To a new operator, the GPS is complex and can initially increase the user's workload. Pilots and observers *must read the operating manual or instructions* and become thoroughly familiar with GPS operation before flight, so that operating the GPS *will not become a distraction* from more important tasks. Also, many manufacturers have CD simulators (e.g., U.S. Aviation Technologies' Apollo GX55; www.upsat.com) that allow individuals to practice use of the GPS on a computer.

Figure 8-10

All GPS units typically display bearing and distance to a waypoint, altitude, ground speed, estimated time to the waypoint (ETE), and ground track. GPS databases also contain extensive information about a selected waypoint (e.g., an airport) such as runway length and alignment, lighting, approaches, frequencies, and even FBO details such as the availability of 100LL fuel and hours of operation.

The GPS receiver allows the pilot to:

<u>Fly directly to any position</u>

The ability to fly directly to any position (e.g., an airport, NAVAID's, intersection, or user waypoint) saves time and fuel. This reduces transit time, thus allowing more of the crew's allowed duty day to be spent in the search area.

Any of these positions can be entered as the destination through a simple procedure. Additionally, all GPS have a "Nearest Airport" and "Nearest VOR" function, where you can easily display a list of the nearest airports or VORs and then select it as your destination. Positions can also be grouped into flight plans.

Once the destination is entered into the GPS, the heading and the ground track can be monitored. *By matching the heading and ground track (or keeping the CDI centered), you are automatically compensating for wind and thus flying the shortest possible route to your destination*. The GX55 has a Moving Map feature that simplifies this task.

<u>Fly between any two points</u>

The ability to fly directly between any two points greatly improves search effectiveness. These points, usually defined by latitude and longitude (lat/long), can be flown in either of two ways:

- The points can be entered into the GPS as user-defined waypoints. The waypoints can then be recalled in the same manner as you would display an airport or NAVAID, or they can be entered into a flight plan.
- The pilot can fly between the points by observing the current lat/long display (i.e., a real-time readout of latitude and longitude).

Two factors have reduced search effectiveness in the past: drifting off course due to shifts in wind direction, and drifting off course because of the lack of adequate boundaries (e.g., cross-radials or visible landmarks). Now any search pattern can be flown precisely without relying on cross-radials or ground references. The crew and the mission staff know that a route or area has been covered thoroughly. Also, GPS allows the crew to remain within assigned boundaries, which greatly improves safety when more than one aircraft is in the search area at the same time.

Obviously, the GPS also allows the aircrew to easily and accurately determine their current position and to determine the position of ground sightings. The GPS will display your current position as lat/long coordinates (most accurate), or you can determine distance and heading to airports, VORs or user waypoints and plot your position accordingly.

The Apollo GX55 has a "moving map," which greatly enhances situational awareness. It shows aeronautical and ground features in (scalable) detail, and also displays special use airspace. Another feature, added to the unit for SAR use, is the SAR MAP mode. This feature allows you to select, define and fly directly to a search grid, and to superimpose a search pattern on the grid (e.g., parallel, creeping line or expanding square). See Chapter 11 and Attachment 2.

8.6 Sectional Charts

The most important tool you will use in both mission flight planning and execution is the chart. Although the earth is spherical, not flat, cartographers can portray small portions of the earth's surface as though it is a flat surface, without affecting accurate navigation. Visual air navigation charts must have certain basic features including:

- Navigational reference system superimposed over the terrain depiction.
- Identifiable, measurable scale to measure distances.
- Detailed graphic depiction of terrain and culture, or man-made features.

Highway road maps are usually not acceptable for air navigation, since most don't have detailed terrain depiction and also lack the superimposed reference system. Many aeronautical charts have such small scales that the makers are unable to show required levels of detail when trying to put a large area into a small chart space. The most useful chart that has been widely accepted for visual, low-altitude navigation is the *sectional aeronautical chart,* sometimes simply referred to as the *"sectional".*

Sectionals use a scale of one to five hundred thousand, or 1:500,000, where all features are shown 1/500,000 of their actual size (1 inch = 6.86 nm). This allows accurate depiction of both natural and cultural features without significant clutter.

Sectionals portray the following:

- Physical, natural features of the land, including terrain contours or lines of equal elevation.
- Man-made or cultural development, like cities, towns, towers, and racetracks.
- Visual and radio aids to navigation, airways, and special-use airspace.
- Airports and airport data, lines of magnetic variation, controlled airspace, obstructions and other important information.
- VFR waypoints.
- Obstructions to flight.

An often overlooked but vital part of the sectional (or any other chart) is the 'Legend.' This is a written explanation of symbols, projections, and other features used on the chart. Figure 8-11 illustrates a portion of the St. Louis sectional chart legend. Other important areas of the sectional chart are its title page or "panel", and the margins around the chart edges. The margins contain supplemental radio frequency information, details about military or *special use airspace,* and other applicable regulations. The title panel identifies the region of the country shown by the chart, indicates the scale used in drawing the chart, explains elevations and contour shading, and shows the expiration date of the chart and effective date of the next issue of that chart. Expired charts should not be used on missions because information on the charts may no longer be correct.

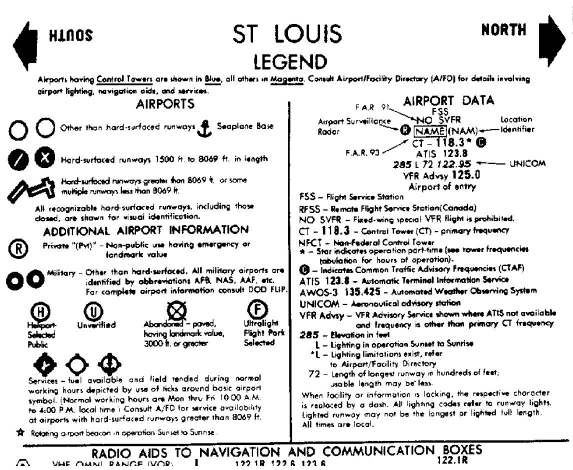


Figure 8-11

Another chart commonly used by VFR pilots is the VFR Terminal Area Charts. The scale of a VFR Terminal Area Chart is 1:250,000 (1 inch = 3.43 nm). The information found on these charts is similar to that found on sectional charts, but the larger scale provides more detail and allows more precise navigation in busy airspace (e.g., Dallas/Ft. Worth Class B airspace).

Both the Sectional and VFR Terminal Area Charts are revised semi-annually. *It is vitally important that you keep current charts in the aircraft at all times*. Obsolete charts should be discarded and replaced by new editions. To make certain that your sectionals are up-to-date, you can refer to the National Ocean Survey (NOS) Aeronautical Chart Bulletin in the Airport/Facility Directory. This bulletin provides the VFR pilot with the essential information necessary to update and maintain current charts. It lists the major changes in aeronautical information that have occurred since the last publication date of each chart, such as:

- Changes to airports, controlled airspace and radio frequencies.
- Temporary or permanent closing of runways or navigational aids.
- Changes special use airspace that present hazardous conditions or impose restrictions on the pilot.

8.7 Chart Interpretation

A significant part of air navigation involves interpreting what one sees on the chart, then making comparisons outside the aircraft. It is most important that observers be thoroughly acquainted with the chart symbols explained in the chart legend, and the relief information discussed on the chart's title panel.

Basic chart symbols can be grouped into cultural features, drainage features, and relief features. Understanding cultural features is straightforward, and they usually require little explanation. Villages, towns, cities, railroads, highways, airports or landing strips, power transmission lines, towers, mines, and wells are all examples of cultural features. The chart legend explains the symbols used for most cultural features, but if no standard symbol exists for a feature of navigational significance, the cartographer frequently resorts to printing the name of the feature itself, such as *factory* or *prison,* on the chart*.*

Drainage features on charts include lakes, streams, canals, swamps, and other bodies of water. On sectional charts these features are represented by lightweight solid blue lines for rivers and streams; large areas of water, such as lakes and reservoirs, are shaded light blue with the edges defined by lightweight solid blue lines. Under most conditions, the drainage features on a map closely resemble the actual bodies of water. However, certain bodies of water may change shape with the season, or after heavy rains or drought. Where this shape change occurs with predictability, cartographers frequently illustrate the maximum size expected for a body of water with light-weight, blue, dashed lines. If you intend to use drainage features for navigation, you should consider recent rains or dry spells while planning and remember the body of water may not appear exactly as depicted on the chart.

8.7.1 Relief

Relief features indicate vertical topography of the land including mountains, valleys, hills, plains, and plateaus. Common methods of depicting relief features are contour lines, shading, color gradient tints, and spot elevations. Contour lines are the most common method of depicting vertical relief on charts. The lines do not represent topographical features themselves, but through careful study and interpretation, you can predict a feature's physical appearance without actually seeing it. Each contour line represents a continuous imaginary line on the ground on which all points have the same elevation above or below sea level, or the zero contours. Actual elevations above sea level of many contour lines are designated by a small break in the line, while others are not labeled. Contour interval, or vertical height between each line, is indicated on the title panel of sectionals.

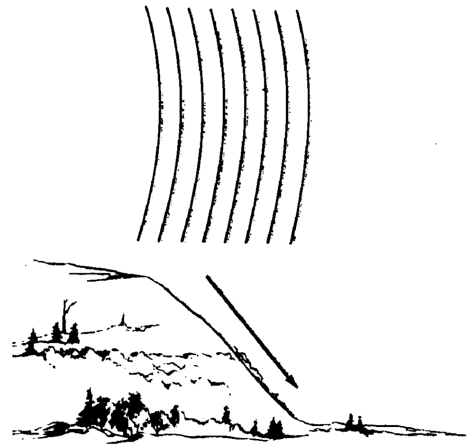


Figure 8-12

Contour lines are most useful in helping us to visualize vertical development of land features. Contour lines that are grouped very closely together, as in Figure 8-12, indicate rapidly changing terrain, such as a cliff or mountain. More widely spaced lines indicate more gentle slopes. Absence of lines indicates flat terrain. Contour lines can also show changes in the slope of terrain. Figures 8-13 and 8-14 show how to predict the appearances of two hillsides based upon their depictions on a chart.

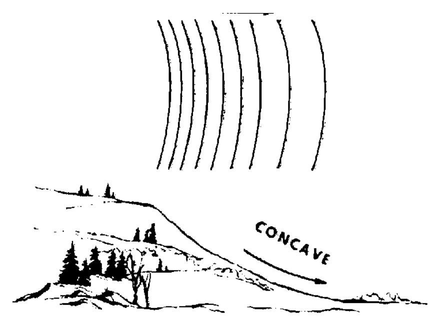


Figure 8-13

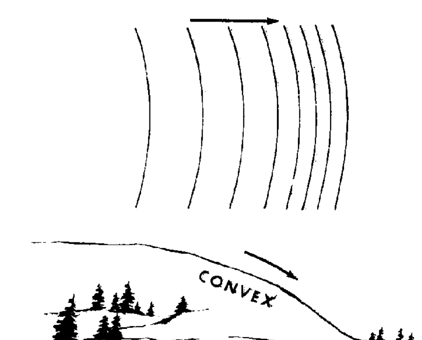


Figure 8-14

Precise portrayal and interpretation of contour lines allows accurate prediction of the appearance of terrain you expect to fly over or near. Figure 8-15 shows the depiction of a saddle in a short ridgeline, and Figure 8-16 shows how it might appear from the aircraft. Many other types of terrain features can be predicted by careful study of contour lines. An outdated chart can be a useful tool for helping to develop your skills, but don't use it in flight.

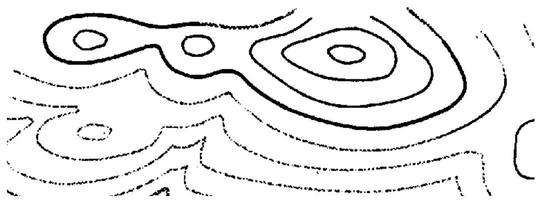


Figure 8-15

Figure 8-16

Shading is added to sectional charts to help highlight and give contrast to the contour lines. These tiny gray dots are applied adjacent to selected contour lines and give the contours a three-dimensional appearance. This makes it easier to imagine the physical appearance of the shaded topographical feature.

Gradient tints, the "background" colors on charts, indicate general areas of elevation. The height range assigned to each gradient color is indicated on the title panel of each sectional chart. Areas that are near sea level are pale green, while *high terrain is color-coded a deep red/brown*. Intermediate elevations are indicated by brighter shades of green, tan, or lighter shades of red/brown.

A spot elevation is the height of a specific charted point. On sectional charts, this height is indicated by a number next to a black dot, the number indicating the height of the terrain above sea level.

8.7.2 Aeronautical Data

The aeronautical information on the sectional charts is for the most part self-explanatory. Information concerning very high frequency (VHF) radio facilities such as tower frequencies, omni-directional radio ranges (VOR), and other VHF communications frequencies is shown in blue. A narrow band of blue tint is also used to indicate the centerlines of Victor Airways (VOR civil airways between omni-range stations). Low frequency-medium frequency (LF/MF) radio facilities are shown in magenta (purplish shade of red).

In most instances, FAA navigational aids can be identified by call signs broadcast in International Morse Code. VOR stations and Non-directional Radio Beacons (NDB) use three-letter identifiers that are printed on the chart near the symbol representing the radio facility.

Runway patterns are shown for all airports having permanent hard surfaced runways. These patterns provide for positive identification as landmarks. All recognizable runways, including those that may be closed, are shown to aid in visual identification. Airports and information pertaining to airports having an airport traffic area (operating control tower) are shown in blue. All other airports and information pertaining to these airports are shown in magenta adjacent to the airport symbol that is also in magenta.

The symbol for obstructions is another important feature. The elevation of the top of obstructions above sea level is given in blue figures (without parentheses) adjacent to the obstruction symbol.

Immediately below this set of figures is another set of lighter blue figures (enclosed in parentheses) that represent the height of the top of the obstruction above ground-level. Obstructions which extend less than 1,000 feet above the terrain are shown by one type of symbol and those obstructions that extend 1,000 feet or higher above ground level are indicated by a different symbol (see sectional chart). Specific elevations of certain high points in terrain are shown on charts by dots accompanied by small black figures indicating the number of feet above sea level.

The chart also contains larger bold face blue numbers that denote Maximum Elevation Figures (MEF). These figures are shown in quadrangles bounded by ticked lines of latitude and longitude, and are represented in thousands and hundreds of feet above mean sea level. The MEF is based on information available concerning the highest known feature in each quadrangle, including terrain and obstructions (e.g., trees, towers, and antennas).

Since Search aircraft regularly fly at or below 1000' AGL, aircrews should exercise extreme caution because of the numerous structures extending up as high as 1000' – 2000' AGL. Additionally, guy wires that are difficult to see even in clear weather support most truss-type structures; these wires can extend approximately 1500 feet horizontally from a structure. Therefore, all truss-type structures should be avoided by at least 2000 feet (horizontally and vertically).

Overhead transmission and utility lines often span approaches to runways and scenic flyways such as lakes, rivers and canyons. The supporting structures of these lines may not always be readily visible and the wires may be virtually invisible under certain conditions. Most of these installations do not meet criteria that determine them to be obstructions to air navigation and therefore, do not require marking and/or lighting. The supporting structures of some overhead transmission lines are equipped with flashing strobe lights, which indicate that wires exist between the strobe-equipped structures. Also, some lines have large orange “balls” spaced along their length.

An explanation for most symbols used on aeronautical charts appears in the margin of the chart. Additional information appears at the bottom of the chart.

8.8 Chart Preparation

Careful chart preparation and route study before the flight can increase your efficiency and decrease your workload during the flight. You should try to develop a systematic approach to chart preparation.

The first step in planning any leg is to locate the departure point and destination on the chart, and lay the edge of a special protractor, or plotter, along a line connecting the two points, as shown in Figure 8-17. Read the true course for this leg by sliding the plotter left or right until the center point, or grommet, sits on top of a line of longitude. When the course is more to the north or south, you can measure it by centering the grommet on a parallel of latitude, then reading the course from the inner scale that’s closer to the grommet.

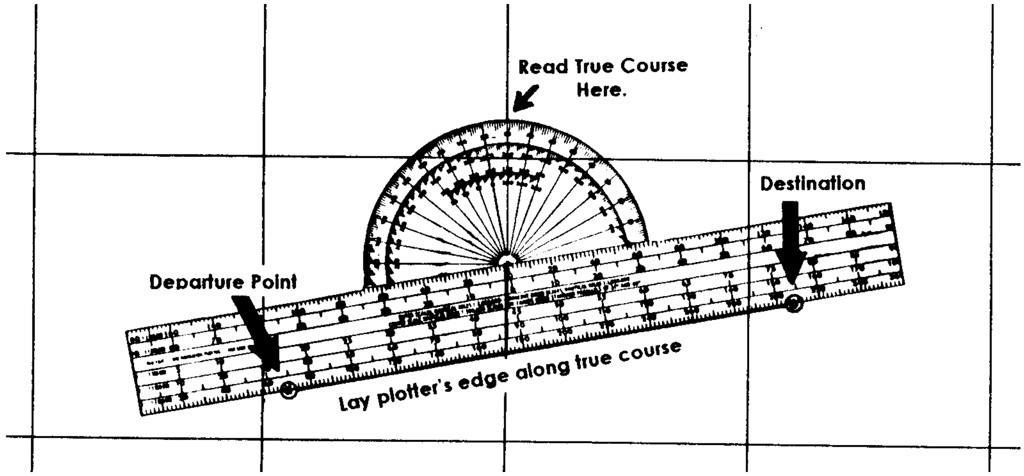


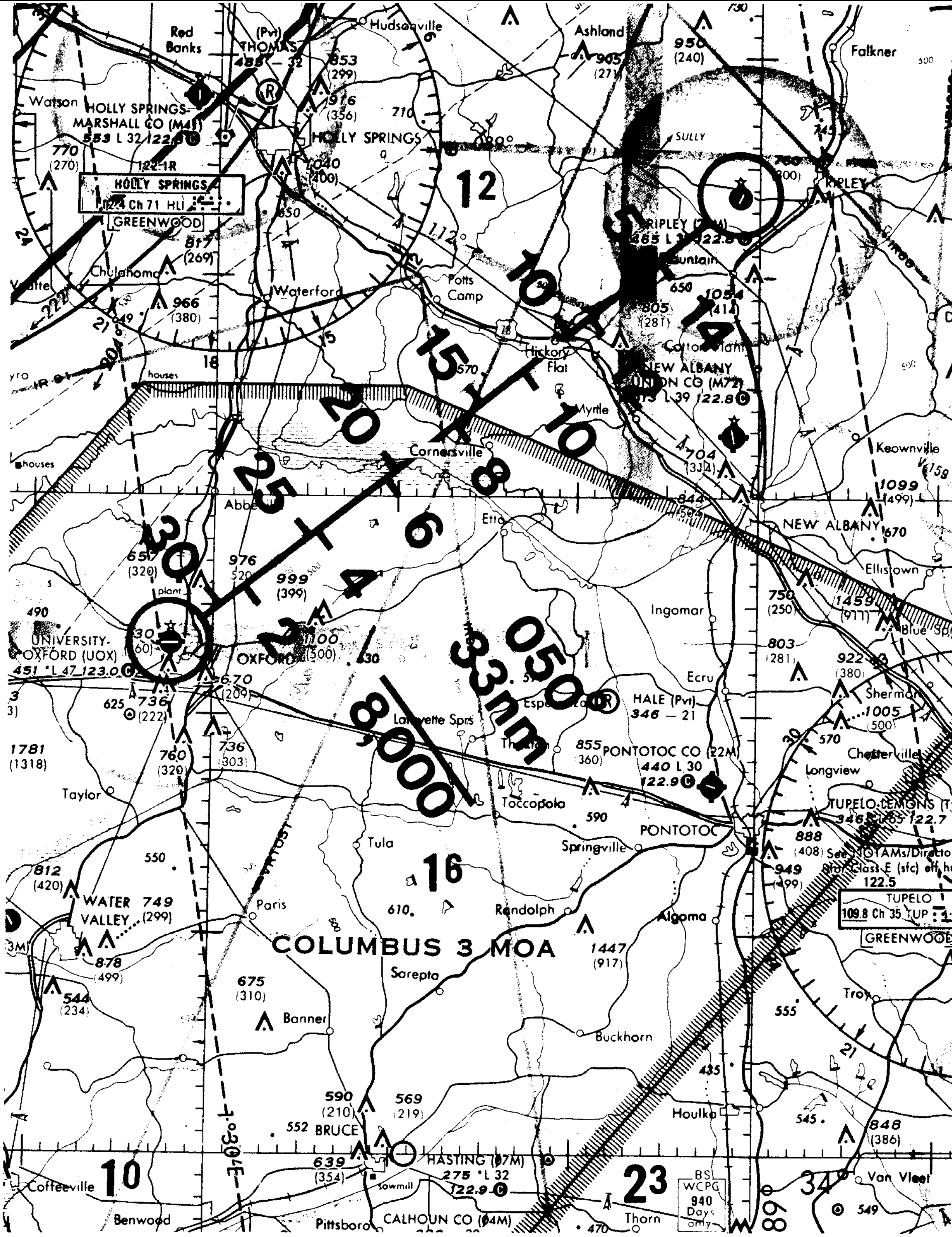
Figure 8-17

The discussion that follows concerns one leg of a flight from University-Oxford airport, near Oxford, Mississippi, to the Ripley airport, near Ripley, Mississippi. The same basic principles used in planning this single leg are used in all air navigation and apply to more complex search patterns.

In Figure 8-18, the chart for this "flight", the two points are connected with a solid line. This line represents the *true* course from Oxford to Ripley and is 051°. If you were interested in going the opposite direction, the course would be the *reciprocal* course, 231°, which also appears on the arc of the plotter. Remain aware of the relationship among general directions -- north, east, south, and west -- and their directions indicated by degrees on the compass -- 000, 090, 180, and 270, respectively. Since almost all charts are printed with north to the top of the chart, you can look at the intended direction of flight, which runs right and up, or to the northeast, and know immediately that 051 is correct and 231 is not.

Notice the broken line that nearly passes through the Oxford airport symbol, and follow it toward the bottom of the page. Near the bottom, you'll see the numbers 1°30' E. This is the magnetic variation correction factor for that area.

If you subtract east variation or add west variation to the true course, you can determine the magnetic course. Most fliers advocate writing the "mag" course right on the chart. Round 1° 30' down to 1° and subtract that from the true course to obtain 050 for the magnetic course. Also notice that Oxford is within the boundaries of the Columbus 3 Military Operating Area (MOA). To avoid an unpleasant encounter with a high-speed jet, you can look at the table in the chart's margin, partially shown in Figure 8-19, and determine that jets using this area do not operate below 8,000 feet. You can note this on the chart with a line over 8,000, which means to remain below 8,000 feet.



Red Banks
(Pvt) THOMAS
Hudsonville
Ashland
Falkner
Watson
HOLLY SPRINGS-MARSHALL CO (M41)
553 L 32 122.8
HOLLY SPRINGS
112.4 Ch 71 HLI
GREENWOOD
RIPLEY
SULLY
RIPLEY
Chulahoma
Waterford
Potts Camp
Hickory Flat
NEW ALBANY UNION CO (M72)
Myrtle
Cornersville
Keownville
NEW ALBANY
Ellistown
Etta
Abbeville
Ingomar
UNIVERSITY-OXFORD (UOX)
451 L 47 123.0
OXFORD
Ecru
HALE (Pvt)
346 - 21
Lafayette Sprs
Thaxton
PONTOTOC CO (22M)
440 L 30 122.9
Sherman
Chesterville
Longview
TUPELO LEMONS
Taylor
Toccopola
PONTOTOC
Springville
Tula
WATER VALLEY
Paris
Randolph
Algoma
COLUMBUS 3 MOA
Sarepta
TUPELO
109.8 Ch 35 TUP
GREENWOOD
Troy
Banner
Buckhorn
Houlka
BRUCE
HASTING (07M)
275 L 32
122.9
Coffeeville
Benwood
Pittsboro
CALHOUN CO (04M)
Thorn
Van Vleet
12
16
10
23
050
33nm
8,000

Figure 8-18

Next you must determine the total distance you're going to fly. Measure this using the scale that's printed on the plotter's straight edge, making sure you use a scale appropriate to the scale of the chart. Use the 1:500,000 scale for sectionals. As an alternative, lay a paper's edge along the course line, make pencil marks on the paper's edge at the two airports, and then lay that same edge along the line of longitude. By simply counting the minute marks on the chart's longitude line that fall between those two pencil marks, you can determine the distance between the two airports in nautical miles. In the example, Oxford and Ripley are 33 nm, or 33 nautical miles, apart.

There are a number of ways you can add information to your chart that will help during the flight. Each flier has his own techniques or variations of the techniques presented here, and over time, you will develop a preference for methods that work best for you.

Tick marks along the course line at specific intervals will help you keep track of your position during flight. Some individuals prefer 5 or 10 nm intervals for tick marks, while others prefer 2 or 4 nm intervals. Four-nautical mile spacing works well for aircraft that operate at approximately 120 knots. Since the 120-knot airplane travels 2 nm every minute, each 4 nm tick mark represents approximately two minutes of flight time. This will become more significant when you study navigational methods in later paragraphs. On the example chart, you have tick marks on the right side of the course line at 4 nm intervals. If the search airplane has an airspeed indicator marked in miles per hour instead of knots, it may be advantageous to space the tick marks in statute mile intervals.

On the left side of the course line you have more tick marks, at 5 nm intervals, but measured backward from the destination. In flight, these continuously indicate distance remaining to the destination. Later in this chapter you will learn about radio aids to navigation that you can use to continuously confirm remaining distance.

The next step in preparing the chart is to identify "*check points*" along the course; you can use these to check your position on or off course, and the timing along the leg. Prominent features that will be easily seen from the air make the best checkpoints, and many fliers like to circle them or highlight them with a marker in advance. On the example, you might expect to see the large towers east of Oxford about 3 nm to your right shortly after take off, and expect later to see the town of Cornersville. Shortly thereafter, you expect to see the road and railroad bend east of Hickory Flat, followed by the Ripley Airport itself. In the example, the checkpoints are widely spaced, but on actual missions checkpoint spacing will be controlled by the search altitude and weather conditions and visibility at the time of the flight.

MOA NAME	ALTITUDE OF USE	TIME OF USE	CONTROLLING AGENCY
ANNE HIGH	7,000	SR - SS MON - FRI	ZFW CNTR
BIRMINGHAM	10,000	0700-2200	ZTL CNTR
COLUMBUS 1, 2, & 3	8,000	SR - SS MON - FRI	ZME CNTR
MERIDIAN 1 EAST	8,000	SR - SS MON - FRI	ZME CNTR
Altitudes indicate floor of MOA. All MOAs extend to but do not include FL180 unless otherwise indicated in tabulation or on chart.			

Figure 8-9

Other information that may be written on the chart includes estimated times of arrival (ETAs) at each checkpoint and reminders like "check gas", "switch tanks", or "contact mission base". Crewmembers are likely to spend less time "fishing" about the cockpit trying to find information in flight if it is already written on the chart.

8.8.1 Plotting the Course

Lay the chart on a table or other flat surface, and draw a straight line from your point of departure to the destination (airport to airport). This can be done with a plain ruler or, better, with a navigation plotter. Mark off the distance in 10 or 20-mile intervals. Use a sharp pencil, making sure the line is straight and that it intersects the center of the airport symbol. Make a careful study of the intervening country and decide whether to fly direct or whether a detour may be desirable in order to avoid flying over large bodies of water, mountains, or other hazardous terrain. Note whether landing fields are available enroute for refueling or use in case of an emergency. Using an appropriate groundspeed and the actual distance to destination, estimate your time enroute. You should know the range (in fuel hours) of the aircraft you intend to fly. From this you can determine whether or not you can make the flight without fueling stops. Be sure to allow at least a one-hour reserve fuel supply.

8.8.2 Checkpoints

Now that you have established a definite course from departure to destination, study the terrain on the chart and choose suitable checkpoints. These can be distinctive patterns: railroad tracks or highways, sharp bends in rivers, racetracks, quarries, and small lakes. As your flight progresses, the checkpoints will be used to maintain the correct course and to estimate the groundspeed. Your checkpoints need not be on your direct line of flight, but should be near enough to be easily seen. For this part of the preflight planning it is essential that you know the chart symbols (explained on the back of the chart) in order to recognize the many landmarks available as checkpoints.

8.8.3 Enclosing the Course

This consists of using an easily recognizable feature on the terrain that lies parallel to your course. It may serve as a guideline or bracket, and may be a river, railroad track, or a prominent highway. The ideal arrangement would be to have a continuous guideline on each side of the route five to 10 miles from the line of flight. It is seldom that two can be found, but one will usually serve satisfactorily. If you should temporarily lose your checkpoints, you can fly to this chosen guideline and reset course. Another landmark should be used as an end-of- course check to prevent flying beyond your destination should you miss it or actually fly directly over it.

8.8.4 True Course

Having plotted your course and made an accurate listing of checkpoints and the distances between them, measure the true course counting clockwise from true north. Use the meridian (north-south) line approximately midway between departure and destination. Your true course can be measured with a common protractor, or better still with a navigation plotter.

When using the GPS, the pilot will be able to easily follow the precise true course between departure point and destination. Without the GPS, magnetic variation, wind and compass deviation would affect the aircraft's ground track.

8.9 Tracking and Recording Position

We have discussed how to use navigational aids and a sectional chart to plot and navigate a course; the same principles are used during flight to keep track of the aircraft's current position and to record sightings. VORs, DME and the GPS are excellent tools that allow you to fix your current position. This information, in turn, allows a crewmember to plot that position on a sectional chart.

Being able to record and report the position of a ground feature is a critical skill in all ES missions (e.g., search and rescue, disaster relied and assessment, CD, and homeland security). Once an aircrew locates a downed aircraft or determines the location of a breech in a levy, they must be able to pinpoint the location on the sectional and report that position to others. Since the details on the sectional chart are often not detailed enough to be useful to ground units, the scanner or observer usually has to transfer that information to a map (e.g., road or topographical).

The state of knowing where you (the aircraft) are at all times is a large part of "maintaining situational awareness" (see Chapter 14 for further discussion on situational awareness). NAVAID allow you to fix your position with great accuracy, and ground features that you can relate to the sectional chart provide confirmation of what your NAVAID's are telling you about your position. In some situations you may not be able to receive signals from VORs or NDBs, and the GPS may be your only useful NAVAID; if the GPS fails, then recording you position on the sectional chart is your only means of position determination.

Knowing the aircraft's position at all times is essential if an in-flight emergency should occur. Equipment malfunctions, an electrical fire, or a medical emergency can necessitate landing at the nearest airport: if you don't know where you are, how can you find the nearest airfield?

8.10 Standardized Grid Systems

A grid is a network of regularly spaced horizontal and vertical lines used to help quickly locate points on a map. Most city street maps have grid systems that help motorists locate streets or other points of interest. A commonly used grid system on city street maps involves numerical and alphabetical references. Regularly spaced letters may be printed across the top of such a map designating imaginary vertical columns, while regularly spaced numbers are printed down the sides of the map designating imaginary horizontal rows. If you want to find Maple Street and the map directory indicates Maple Street is located in section K-5, you then look at or near the intersection of column K with row 5. Within that area, you should find Maple Street.

Air Search and Rescue units have found it useful to construct similar grid systems on aeronautical charts for search and rescue operations. Some maps, like city maps, already have grid systems constructed on them, but aeronautical charts typically do not. You can construct a grid system on any type of chart or map. You may use numbers and letters like street maps, or you could use only numbers. In either case, the system should give *every* user a common, standardized method for identifying a location according to its position within the grid. It is very easy to exchange location information over the radio using the grid system. With the known grid positions, other team members can quickly determine on their own charts the location of a sighting or point of interest.

Grid systems are especially helpful when locating a position that has no nearby distinguishable landmarks or features, such as buildings, roads, or lakes. Grid systems will work anywhere, even in the middle of large lakes, in deep woods, or in swamps. Anyone can develop a workable system provided that all members of the search team use the same grid system.

8.10.1 Sectional Chart Grids

WSDOT - Aviation has adopted a standard grid system built upon the matrix of parallels of latitude and meridians of longitude and the sectional aeronautical chart. Sectional charts cover a land area approximately seven degrees of longitude in width and four degrees of latitude in height. Information pertaining to gridding can be found in Attachment E of the *U.S. National SAR Supplement to the International Aeronautical and Maritime SAR Manual* (Attachment 1).

Table 8-1 shows the latitude and longitude boundaries of each sectional chart. The Seattle chart, for example, covers an area that is bounded by the following latitudes and longitudes: North 49° 00’ (north boundary), North 44° 30’ (south boundary), West 125°-00’ (west boundary), and West 117°-00’(east boundary).

Chart	Identifier	North Grid Limit	South Grid Limit	West Grid Limit	East Grid Limit	Total Grids
Seattle	SEA	49-00N	44-30N	125-00W	117.00W	576
Great Falls	GTF	49-00N	44-30N	117-00W	109-00W	576
Billings	BIL	49-00N	44-30N	109-00W	101-00W	576
Twin Cities	MSP	49-00N	44-30N	101-00W	93-00W	576
Green Bay	GRB	48-15N	44-00N	93-00W	85-00W	544
Lake Huron	LHN	48-00N	44-00N	85-00W	77-00W	512
Montreal	MON	48-00N	44-00N	77-00W	69-00W	512
Halifax	HFX	48-00N	44-00N	69-00W	61-00W	512
Klamath Falls	LMT	44-30N	40-00N	125-00W	117-00W	576
Salt Lake City	SLC	44-30N	40-00N	117-00W	109-00W	576
Cheyenne	CYS	44-30N	40-00N	109-00W	101-00W	576
Omaha	OMA	44-30N	40-00N	101-00W	93-00W	576
Chicago	ORD	44-00N	40-00N	93-00W	85-00W	512
Detroit	DET	44-00N	40-00N	85-00W	77-00W	512
New York	NYC	44-00N	40-00N	77-00W	69-00W	512
San Francisco	SFO	40-00N	36-00N	125-00W	118-00W	448
Las Vegas	LAS	40-00N	35-45N	118-00W	111-00W	476
Denver	DEN	40-00N	35-45N	111-00W	104-00W	476
Wichita	ICT	40-00N	36-00N	104-00W	97-00W	448
Kansas City	MKC	40-00N	36-00N	97-00W	90-00W	448
St. Louis	STL	40-00N	36-00N	91-00W	84-00W	448
Cincinnati	CVG	40-00N	36-00N	85-00W	78-00W	448
Washington	DCA	40-00N	36-00N	79-00W	72-00W	448
Los Angeles	LAX	36-00N	32-00N	121-30W	115-00W	416
Phoenix	PHX	35-45N	31-15N	116-00W	109-00W	504
Albuquerque	ABQ	36-00N	32-00N	109-00W	102-00W	448
Dallas-Fort	DFW	36-00N	32-00N	102-00W	95-00W	448
Worth	MEM	36-00N	32-00N	95-00W	88-00W	448
Memphis	ATL	36-00N	32-00N	88-00W	81-00W	448
Atlanta	CLT	36-00N	32-00N	81-00W	75-00W	384
Charlotte						

Table 8-1

The sectional grid system used by WSDOT - Aviation divides each sectional's area into smaller squares. This process begins by dividing the whole area into *1-degree* grids, using whole degrees of latitude and longitude as shown in Figure 8-19. Then each 1-degree grid is divided into four *30-minute* grids, using the 30-minute latitude and longitude lines as shown in Figure 8-20. Finally, each of the 30-minute grids is divided into four *15-minute* grids, using the 15- and 45-minute latitude and longitude lines as shown in Figure 8-21.

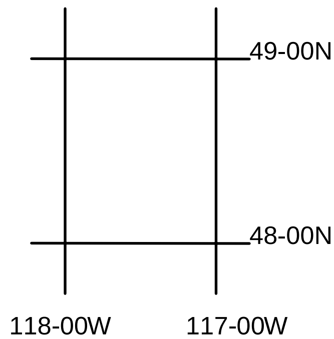


Figure 8-10

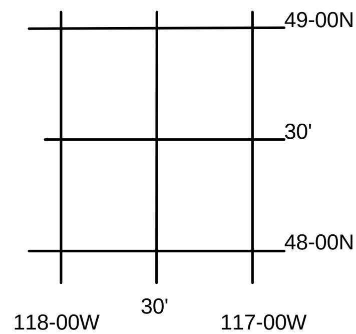


Figure 8-11

Next, the grid squares are numbered 1 through 576 beginning with the most northwest square on the entire sectional, and continuing straight east through number 32. The numbering resumes in the second row, with number 33 placed beneath number 1, 34 beneath 2, and so on through 64. The third row begins with number 65 beneath numbers 1 and 33, and continues through 96. Numbering continues through successive rows until all 576 squares have a number.

In Figure 8-21, each 15-minute grid square has the number it would have received if this demonstration had started with the entire Seattle sectional chart.

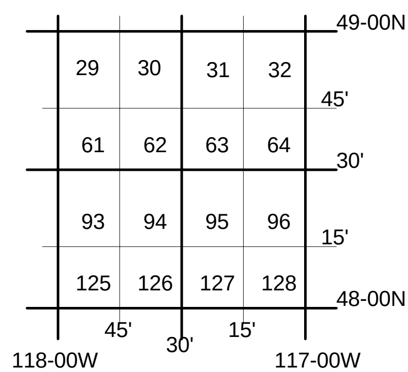


Figure 8-12

Returning to Table 8-1, notice that the eastern limit of the Kansas City sectional grid, 90° 00'W, is one full degree of longitude east of the western limit of the St. Louis sectional, 91° 00' W. The two sectionals overlap by one full degree of longitude. When drawing a grid over this overlap area, which numbers would you assign to these grid squares, the Kansas City or St. Louis grid numbering?

When circumstances require, a 15-minute grid can be divided into 4 more quadrants using 7 1/2 degree increments of latitude and longitude, creating 4 equal size grids that are approximately 7 1/2 miles square. The quadrants are then identified alphabetically - A through D - starting with the northwest quadrant as A, northeast as B, southwest as C and southeast as D, as in Figure 8-22. A search area assignment in the southeast quadrant may be given as "Search SEA 5D."

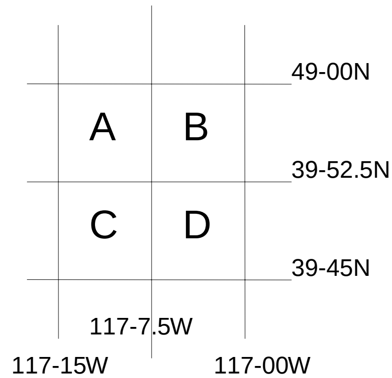


Figure 8-13

Pinpointing an area within the grid system becomes easy once you gain familiarity with the grids' many uses. You soon will be able to quickly plot any area on a map and then fly to it using the basic navigation techniques already discussed.

Chapter

9

9. Search Planning and Coverage

This chapter will cover factors that are unique to SAR/DR mission planning. Planning considerations and techniques used in both visual and electronic search missions are included. The incident commander and his general staff perform much of the planning. However, all crewmembers are expected to understand the planning concepts. This comprehension allows more precise mission performance, and increases flexibility to effectively deal with changing circumstances. Much of this information is contained in the *U.S. National SAR Supplement to the International Aeronautical and Maritime SAR Manual*.

OBJECTIVES:

1. Define the following search terms:
    a. Ground and Search Track.
    b. Maximum Area of Possibility.
    c. Meteorological and Search Visibility.
    d. Probability Area.
    e. Probability of Detection (POD).
    f. Scanning Range.
    g. Search Altitude.
    h. Track spacing (S).
2. In basic terms, discuss how search planners determine the Maximum Area of Possibility and then the Probability Area.
3. Given a POD table, discuss the advantages and disadvantages of various search altitudes and speeds over the three major types of terrain.
4. Discuss the importance of proper execution of search patterns.
5. Discuss how a disaster can effect operations.
6. Discuss the types of questions you must always be asking yourself during damage assessment missions.
7. List typical things you are looking for during a damage assessment mission.
8. List the information you should obtain when over a damage assessment site.
9. Discuss the limitations of an air search for a missing person.

9.1 Search Terms

A number of terms and planning factors must be understood when planning and executing search and rescue missions.

Ground Track - an imaginary line on the ground that is made by an aircraft's flight path over the ground.

Maximum Area of Possibility - this normally circular area is centered at the missing airplane's (or search objective's) last known position (LKP), corrected for the effect of wind. The circle's radius represents the maximum distance a missing aircraft might have flown based on estimated fuel endurance time and corrected for the effects of the wind over that same amount of time. The radius may also represent the maximum distance survivors might have traveled on foot, corrected for environmental or topographical conditions, such as snow, wind, mountains, and rivers.

Meteorological Visibility - the maximum distance at which large objects, such as a mountain, can be seen.

Probability Area - this is a smaller area, within the maximum possibility area, where, in the judgment of the incident commander or planner, there is an increased likelihood of locating the objective aircraft or survivor. Distress signals, sightings, radar track data, and the flight plan are typical factors that help define the probability area's boundaries.

Probability of Detection - the likelihood, expressed in a percent, that a search airplane might locate the objective. Probability of detection (POD) can be affected by weather, terrain, vegetation, skill of the search crew, and numerous other factors. When planning search missions, it is obviously more economical and most beneficial to survivors if we use a search altitude and track spacing that increases POD to the maximum, consistent with the flight conditions, team member experience levels, and safety. Note: POD will be decreased if only one scanner is on board and the search pattern is not adjusted accordingly.

Scanning Range - the lateral distance from a scanner's search aircraft to an imaginary line on the ground parallel to the search aircraft's ground track. Within the area formed by the ground track and scanning range, the scanner is expected to have a good chance at spotting the search objective. Scanning range can be less than but never greater than the search visibility.

Search Altitude - this is the altitude that the search aircraft flies above the ground (AGL). [Remember, routine flight planning and execution deals in MSL, while searches and assessments are referenced to AGL.]

Search Track - an imaginary swath across the surface, or ground. The scanning range and the length of the aircraft's ground track forms its dimensions.

Search Visibility - the distance at which an object on the ground (an automobile is used as a familiar example) can be seen and recognized from a given height above the ground. Search visibility is always less than meteorological visibility. [Note that on the POD chart that the maximum search visibility listed is four nautical miles.]

Track Spacing - the distance (S) between adjacent ground tracks. The idea here is for each search track to either touch or slightly overlap the previous one. It is the pilot's task to navigate so that the aircraft's ground track develops proper track spacing.

9.2 Search Planning

When faced with a lack of vital information concerning the missing aircraft, the planner can either give the entire probability area search priority or select a portion of the probability area for a concentrated search. Some of the factors used in estimating the location of the missing aircraft within a portion of the probability area are:

- Areas of thunderstorm activity, severe turbulence, icing and frontal conditions.
- Areas where low clouds or poor visibility may have been encountered.
- Deviations in wind velocities from those forecast by the weather bureau.
- Areas of high ground.
- Any part of the aircraft's track that is not covered by radar.

9.2.1 Search Area Determination

The first task in planning a search and rescue mission is to establish the most probable position of the crash site or survivors. If witnesses or other sources provide reliable information concerning an accident, the location may be established without difficulty. If there is little or no information, the planner faces a more difficult task. Regardless of the information available, the planner always prepares a chart to assist in focusing the search and locating the crash site or survivors as quickly as possible.

When defining search area limits, the planner first sketches the maximum possibility area. This can focus the initial search in the most likely area and allows use of the charted area to help screen sightings and other reports. Again, the area is roughly circular, centered on the last known position of the missing aircraft. The radius approximates the distance the objective aircraft might have traveled, given the amount of fuel believed aboard at its last known position, and the wind direction and speed. The area is circular because it's always possible the missing pilot may have changed directions following his last known position and flown until his fuel was exhausted.

To chart the Maximum Area of Possibility, the planner requires the missing aircraft's last known position, wind direction and velocity, and an estimate of the missing aircraft's fuel endurance and airspeed. Figure 9-1 illustrates the use of these factors to chart the maximum area of possibility. The planner plots the missing aircraft's last known position on a sectional or other chart, then displaces the position for 2 hours of wind effect, or 40 nm, from 330°. From the displaced last known position, he draws a circle with a radius equal to the maximum distance flown by the aircraft. In this case, the planner estimated this range by multiplying aircraft speed, in this case 100 kts, by the estimated endurance of 2 hours.

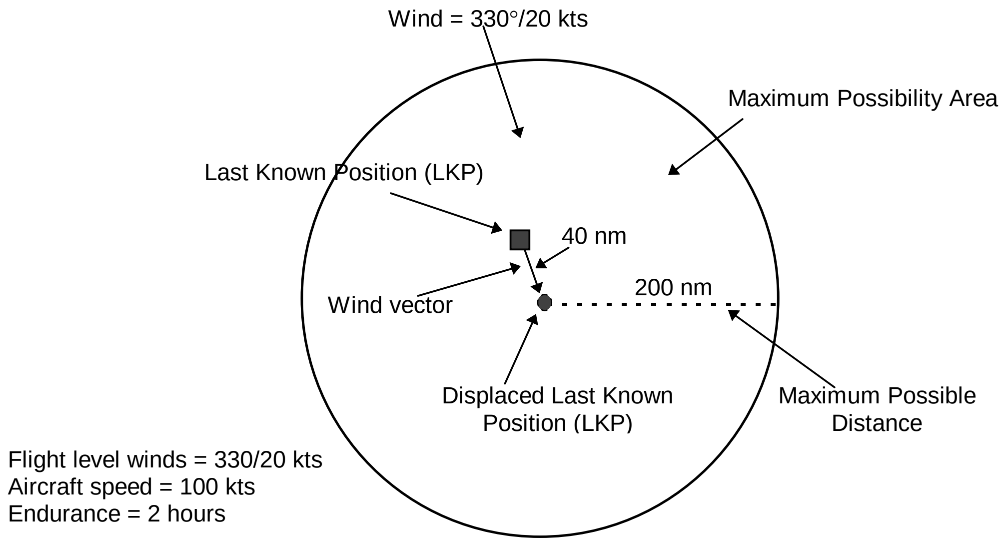


Figure 9-1

Radar nets provide almost complete coverage of the continental U.S., Alaska, Hawaii, and Puerto Rico. The National Track Analysis Program (NTAP) can retrieve computer-sorted radar data up to 15 days old to pinpoint a missing aircraft's last known position (LKP). NTAP information should be requested through AFRCC.

Other FAA recording radar nets include Air Route Traffic Control Centers (ARTCC) facilities and Terminal Radar Approach Control (TRACON) facilities. Both record primary and secondary radar data that is retained for 15 days and may be obtained in hard copy format.

9.2.2 Probability areas

Plotting the probability area, the area in the possibility circle where the searchers are most likely to find the aircraft, is the second major factor in search planning. The probability area is determined by the accuracy of the last known position (LKP) in the possibility circle. Primary factors that contribute to the accuracy of the LKP are:

- The aircraft disappearance point on radar.
- The bearing or fix provided by other ground stations.
- Dead reckoning position based on the time of LKP.
- Reports of sightings-either ground or air.
- Emergency locator transmitter (ELT) reports.

There are instances where the above information is not available to assist the planner. To establish a probable position in these instances, the planner must rely on less specific secondary sources of information including:

- Flight plan.
- Weather information along the intended route or track.
- Proximity of airfields along route.

- Aircraft performance.
- Pilot's previous flying record.
- Radar coverage along the intended track.
- Nature of terrain along the intended track.
- Position and ground reports.

Based on experience and simulation provided by these factors, the planner is able to define an area of highest priority to initiate the search. The first search area may be called probability area one. This area begins around the last known position, extends along the intended route and ends around the intended destination. If a search of probability area one produces negative results, the search may be expanded to cover probability area two, an extension of area one.

Organization is an important element in search planning. The time it takes to locate downed aircraft or survivors could depend on the definition and charting of the search area. As a pilot or observer, you should become familiar with each designated search area before the mission is launched. You should use current charts and maps which will enable you to provide additional navigational assistance in accurately positioning the search aircraft over the properly designated area.

Outlining the maximum area of possibility establishes an *initial* likely area where the missing aircraft might be located. In the earlier example, the maximum possibility area included over 120,000 square miles. The extensive size of the maximum possibility area makes systematic search neither efficient nor practical. It is essential that the planner further focus search assets and attempt to further define the possible location area. To do this, the planner charts a *probability area* within the possibility circle.

The probability area is determined by considering other factors that will help to reduce the area of intended search. These additional factors may include:

- Bearing or fix provided by other, non-radar, ground stations.
- Point where the aircraft disappeared from air traffic control radar.
- Dead reckoning position based on time of last known position.
- Reported sightings from either ground or air.
- SARSAT or emergency locator transmitter reports.
- Missing aircraft's flight plan.
- Weather information along the missing aircraft's intended route.
- Proximity of airfields along that route.
- Aircraft performance.
- Missing pilot's previous flying experience and habits.
- Radar coverage along the intended track.
- Nature of the terrain along the intended route.
- Position and ground reports.

In instances when little information is available to assist the planner, he or she reconstructs the incident flight with whatever information may be available. With no information, the search plan is based on an assumption that the missing aircraft is probably located along or near its intended course. The search is initially confined to an area 5 miles on either side of the intended course, beginning at the last known position and continuing to the intended destination. This first search area is called *probability area one.* The unshaded area in Figure 9-2 represents probability area one.

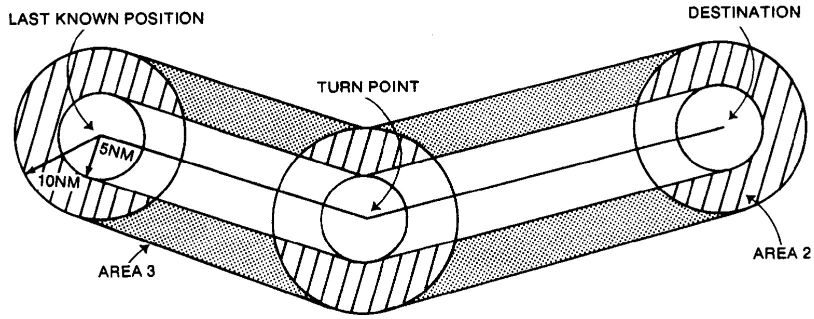


Figure 9-2

If search of probability area one produces no results, the search expands to include the area within a 10-mile radius of the last known position, destination, and intermediate points. This area is known as *probability area two* and is depicted by the hatched areas in Figure 9-2.

If the search still produces no results, a third search area is created. *Probability area three* includes areas 10 miles either side of the missing aircraft's intended course, excluding those areas already searched in areas 1 and 2. Shaded areas in Figure 9-2 illustrate probability area three. If there is still no result, the incident commander may chart a new probability area within the possibility circle.

When other information *is* available that indicates any of the following factors may have been involved, the incident commander may also consider these factors when assigning priority to initial search areas:

- Areas of thunderstorm activity, severe turbulence, icing, frontal conditions, or any other weather condition that may have influenced a pilot to consider alternate routes to the destination.
- Areas where low clouds or poor visibility might have been encountered.
- High terrain or mountain passes.
- Any part of the aircraft's course is not covered by radar.
- Reports of ground sightings or of sound from low-flying aircraft.
- Point of last reported radio contact or MAYDAY broadcast.
- Deviations in wind velocities from those forecast.
- Survival factors.

In many military incidents, crewmembers of aircraft may eject or "bail out" of an aircraft prior to its collision with the ground. This is rare in civilian accidents, but if applicable the planner will also consider parachute drift factors when determining search areas.

9.2.3 Search Altitudes and Airspeeds

Once probability areas are identified, the planner must make a number of choices as to the size and type of search patterns to be flown, search altitudes, and airspeeds. To make effective choices, the planner first considers factors beyond his or her control, including the size of the search objective, visibility, weather, and sea or terrain conditions. Altitude selection will be based on Operational Risk Management criteria, the search environment, and the mission objective.

WSDOT requires pilots to maintain a minimum of 500 feet above the ground, water during daylight hours, and a minimum of 2000' AGL at night (except for takeoff/landing or when under ATC control). For SAR/DR reconnaissance, the pilot will maintain at least 1,000 AGL. Pilots may descend below the designated search altitude to attempt to positively identify the target (but never below 500 AGL); once the target has been identified the pilot will return to 800' AGL or higher.

The size of the search objective, weather, visibility, and ground cover in the search area must be considered when determining the altitude and airspeed for a visual search. Over non-mountainous terrain, a search altitude between 500 and 1500 feet above the terrain is normally used for a visual search. The search visibility and the terrain conditions may affect this selection. As altitude decreases below 1000 feet search effectiveness may actually decrease, due to the "rush effect" of objects on the ground passing through the scanner's field of view more rapidly.

Over mountainous terrain, the search altitude may be higher if the planner suspects wind and turbulence near the surface. During darkness, an altitude 3,000 feet above the terrain is considered adequate. Also, rugged terrain can easily block emergency radio transmissions, so electronic searches over such terrain are normally conducted at considerably higher altitudes than would be used during visual searches.

Depending upon the number of search aircraft available to the incident commander, he may also consider the desired probability of detection when selecting an altitude for the search pattern. Although a probability of detection chart is normally used to estimate POD *after* a search, its use here allows incident commanders to predetermine a mission's chance of success. Here’s an example of using desired POD to help select a search altitude.

A red and white Cessna 172 has been reported missing and presumed down in eastern Arkansas, in open flat terrain. At the time of the search, flight visibility is forecast to be greater than 10 miles. The incident commander determines, based on available aircraft and crews, that the single probability of detection for this first search must be at least 50%.

The POD chart excerpt in Table 9-1 shows data for: open, flat terrain; hilly terrain and/or moderate ground cover; and very hilly and/or heavily covered terrain. To the right in the columns beneath "Search Visibility" you see what are, in this case, the desired probabilities of detection. Looking at the open/flat terrain portion of the table (Table 9-2) and using 1-mile track spacing with 4 nm search visibility, you can see that all three altitudes give at least 50% POD. A search at 1000 feet above the terrain gives 60%, or 12% *more* POD, than does a search at 500 feet. Over open terrain, where flight and search visibility are not limiting factors (i.e., greater than 4 nm), the chart demonstrates that a higher altitude is more likely to yield positive results on a single sortie. Notice that the highest POD in Table 9-2, 85%, is obtained when flying at 1,000 feet above the ground using a track spacing of 0.5 nm.

OPEN, FLAT TERRAIN				
SEARCH ALTITUDE (AGL)	SEARCH VISIBILITY			
Track Spacing	1 mi	2 mi	3 mi	4 mi
500 Ft				
.5 mi	35%	60%	75%	75%
1.0	20	35	50	50
1.5	15	25	35	40
2.0	10	20	30	30
700 Ft				
.5 mi	40%	60%	75%	80%
1.0	20	35	50	55
1.5	15	25	40	40
2.0	10	20	30	35
1000 Ft				
.5 mi	40%	65%	80%	58%
1.0	25	40	55	60
1.5	15	30	40	45
2.0	15	20	30	35

MODERATE TREE COVER AND/OR HILLY				
SEARCH ALTITUDE (AGL)	SEARCH VISIBILITY			
Track Spacing	1 mi	2 mi	3 mi	4 mi
500 Ft				
.5 mi	20%	35%	50%	50%
1.0	10	20	30	30
1.5	5	15	20	20
2.0	5	10	15	15
700 Ft				
.5 mi	20%	35%	50%	55%
1.0	10	20	30	35
1.5	10	15	20	25
2.0	5	10	15	20
1000 Ft				
.5 mi	25%	40%	55%	60%
1.0	15	20	30	35
1.5	10	15	20	25
2.0	5	10	15	20

HEAVY TREE COVER AND OR VERY HILLY				
SEARCH ALTITUDE (AGL)	SEARCH VISIBILITY			
Track Spacing	1 mi	2 mi	3 mi	4 mi
500 Ft				
.5 mi	10%	20%	30%	30%
1.0	5	10	15	15
1.5	5	5	10	15
2.0	5	5	10	10
700 Ft				
.5 mi	10%	30%	30%	35%
1.0	5	10	15	20
1.5	5	5	10	15
2.0	5	5	10	10
1000 Ft				
.5 mi	15%	20%	30%	35%
1.0	5	10	15	20
1.5	5	10	10	15
2.0	5	5	10	10

Table 9-1

OPEN, FLAT TERRAIN				
SEARCH ALTITUDE (AGL)	SEARCH VISIBILITY			
Track Spacing	1 mi	2 mi	3 mi	4 mi
500 Feet				
0.5 nm	35%	60%	75%	75%
1.0	20	35	50	50
1.5	15	25	35	40
2.0	10	20	30	30
700 Feet				
0.5 nm	40%	60%	75%	80%
1.0	20	35	50	55
1.5	15	25	40	40
2.0	10	20	30	35
1,000 Feet				
0.5 nm	40%	65%	80%	**85%**
1.0	25	40	55	60
1.5	15	30	40	45
2.0	15	20	30	35

Table 9-2

If weather or visibility are not limiting factor, why then don't you just always elect to fly *that* track spacing at 1,000 feet, and always try to obtain that highest of probabilities of detection? You should recall, from the earlier maximum probability area, that you start with a very large area and then try to focus your efforts on smaller probability areas within that larger area. If the incident commander has received a number of leads that have reduced the probable area to a small size, he might task you to fly exactly that track spacing and altitude. If the area is not so small, and you try to fly 1/2 rather than 1 nm track spacing, you will obviously take *twice* as long to cover the whole area.

The incident commander also has another option he may use to increase the POD. Given adequate resources of aircraft and crews, he can significantly increase the POD by directing multiple searches of the same area, and increasing the amount of time that search forces cover the probability area. This can be demonstrated by using a Cumulative POD chart, shown in Table 9-3, and the earlier example of the missing red and white Cessna. The single-search POD for this hypothetical search was 60%. That mission was flown at 1,000 feet and 1-nm track spacing. If you, or another aircraft and crew, fly the same pattern a second time, the POD increases significantly. If the same search is flown again, with the exact same parameters for altitude and track spacing, the overall probability of detection (where the initial 60% intersects the subsequent same single POD, also 60%) is now 80% cumulative. A third search of the same area, again using the same parameters, brings the cumulative POD up to 90%. Since the cumulative POD increases with time in the search area, the incident commander has another option he can select to maximize search coverage.

CUMULATIVE POD CHART

Previous, or Cumulative POD									
5-10%	15								
11-20%	20	25							
21-30%	30	35	45						
31-40%	40	45	50	60					
41-50%	50	55	60	65	70				
51-60%	60	65	65	70	75	**80**			
61-70%	70	70	75	80	80	85	90		
71-80%	80	80	80	85	85	90	90	95	
80%+	85	85	90	90	90	95	95	95	95+
	5-10%	11-20%	21-30%	31-40%	41-50%	51-60%	61-70%	71-80%	80%+
	POD THIS SEARCH								

Table 9-3

9.2.4 Executing Search Patterns

The incident commander and his staff take into consideration many variables including weather, visibility, aircraft speed, and availability of aircraft and crew resources, experience, and urgency of the situation when developing the search plan. This section covered a number of factors that can affect the choice for search altitudes and track spacing. Similarly, the planner considers many variables when selecting the search pattern or patterns to be used. Individual search patterns are covered in chapters that follow. All questions about how the search is to be conducted must be resolved at the mission briefing. When airborne, crews must focus on executing the briefed plan instead of second-guessing the general staff and improvising. If, for whatever reason, you deviate from the planned search pattern it is imperative that you inform the staff of this during your debriefing.

9.2.5 Search Coverage Probability of Detection

Before a search mission gets airborne, each aircrew has a good idea of how much effort will be required to locate the search objective if it is in the assigned search area. This effort, expressed as a percentage, is the probability of detection. As a member of a SAR aircrew, you may be required to establish a POD for your aircrew's next sortie.

9.3 Probability of detection example

You can easily determine a probability of detection (POD) by gathering the data affecting the search and by using a POD chart to calculate the detection probability.

The type of terrain, ground foliage, altitude of the search aircraft, track spacing, and search visibility are vital factors in determining a POD. Once each of these factors is given a description or numerical value, the POD can be determined by comparing the search data with the POD chart data. The following discussion is based on this example search situation:

A Cessna 182, white with red striping along the fuselage and tail, was reported missing in the northwest area of Georgia. The last known position of the airplane was 40 miles north of the city of Rome. Geological survey maps indicate that the probability area is very hilly and has dense or heavy tree cover. Current visibility in the area is 3 miles. A search for the airplane and its three occupants is launched using 700 feet AGL for the search altitude and a track spacing of 1.5 miles.

9.3.1 Using the Probability of Detection Table

By referring to a POD chart you will note that there is approximately a 10% chance of locating the missing aircraft during a single search. Locate the numbers in the column describing heavy tree cover and hilly terrain that coincide with the search data mentioned above.

In cases where there are multiple or repeated searches over the same probability area, you should use the cumulative POD chart. This chart is as easy to use as the single search POD chart.

Using the same data that we just mentioned concerning the missing Cessna 182, we can determine the probability of detecting the aircraft during a second search of the probability area. In the first search the POD was ten percent. For the second search (assuming that the data remains the same as was specified for the first search), the POD would be ten percent. However, because this is a repeat, the overall POD increases to 15 percent.

Probably the greatest advantage of using the cumulative POD chart is to indicate to searchers how many times they may have to search a single area to obtain the desired overall POD. For instance, you may want a POD of 80 percent in an area before continuing to another area. If one search of probability area proves futile with a POD of 35 percent and a second search is conducted in the area with a POD of 40 percent, the cumulative POD can be determined easily. The observer in the aircraft would only have to locate the box that intersects the 35 percent POD with the 40 percent POD.

A look at the cumulative POD shows that these two searches would yield a cumulative POD of 60 percent. Therefore, you should search the area again. Remember, the cumulative POD chart should be used when multiple searches are conducted over the same search area.

This general explanation of the cumulative POD chart has provided some basic information about its use. As a mission pilot or observer, you should not concern yourself with extensive calculations involving the cumulative POD. Simply knowing the probability of detection for each mission and the factors contributing to that probability is enough involvement on the mission aircrew's part.

9.3.2 Sample problems

By referring to a POD chart you will note that there is approximately a 10% chance of locating the missing aircraft during a single search. Locate the numbers in the column describing heavy tree cover and hilly terrain that coincide with the search data mentioned above.

Problem #1

Four aircraft have accumulated 9 hours over a given search area at an average ground speed of 90 knots. If they used a track spacing of 2 nm, what is the total area searched in thousands of square miles?

Problem #2

The area to be searched prior to sunset is 6000 square nautical miles. With an average ground speed of 60 knots, 6 hours of good light left in the day, and a track spacing of 1.5 nm, how many aircraft will be required to complete the search?

Problem #3

The area to be searched is 5000 square nautical miles, and the incident commander has selected 2 nm for track spacing. With 3 aircraft capable of an average ground speed of 100 knots, how many hours will the search take?

9.4 Disaster Assessment

WSDOT aircrews may be called upon to assess damage from natural and man-made disasters. Natural disasters may result from weather related phenomena such as earthquakes, floods, wildfires, winter storms, tornados, and hurricanes. Man-made disasters may result from accidents (e.g., chemical, biological or nuclear industrial accidents) or acts of terrorism or war.

One of the most important commodities during disasters is accurate, timely intelligence. During an emergency or disaster, conditions on the ground and in the air can change rapidly and the emergency managers and responders need this information as quickly as possible.

Some of the disaster assessment services that WSDOT Aviation may be asked to provide are:

- Air and ground SAR services (e.g., missing persons, aircraft and livestock).
- Air and ground visual and/or video imaging damage survey and assessment.
- Flood boundary determination using GPS.
- Air and ground transportation of key personnel, medical and other equipment, and critical supplies during actual disaster operations.
- Air transportation of SAR dogs.

- Radio communications support including a high bird relay and control aircraft to extend communications over a wide area or to coordinate air traffic into a TFR area over the disaster site.
- Courier flights.

9.4.1 Effects on operations

The conditions that created the emergency or disaster may affect emergency air operations. Extreme weather is an obvious concern, and must be considered in mission planning.

The disaster may affect the physical landscape by erasing or obscuring landmarks. This may make navigation more difficult and may render existing maps obsolete.

Disasters may also destroy or render unusable some part of the area's infrastructure (e.g., roads, bridges, airfields, utilities and telecommunications). This can hamper mobility and continued operations. Also, road closures by local authorities or periodic utility outages can reduce the effectiveness and sustainability of operations in the area.

9.4.2 Biological, Chemical or Radiological Terrorism

The events of September 11th brought home the need for increased vigilance against weapons of mass destruction. The following provide general precautions for aircrews for the three major threats.

For Biological Terrorism, be alert to the following:

- Groups or individuals becoming ill around the same time.
- Sudden increase in illness in previously health individuals.
- Sudden increase in the following non-specific illnesses: pneumonia, flu-like illness, or fever with atypical features; bleeding disorders; unexplained rashes, and mucosal or dermal irritation; and neuromuscular illness.
- Simultaneous disease outbreaks in human and animal populations.

For Chemical Terrorism, be alert to the following:

- Groups or individuals becoming ill around the same time.
- Sudden increase in illness in previously health individuals.
- Sudden increase in the following non-specific syndromes: sudden unexplained weakness in previously healthy individuals; hyper secretion syndromes (e.g., drooling, tearing, and diarrhea); inhalation syndromes (e.g., eye, nose, throat, chest irritation and shortness of breath); shin burn-like skin syndromes (e.g., redness, blistering, itching and sloughing).

For Ionizing Radiation Terrorism, be alert to the following:

- Nausea and vomiting.

Pocket guides covering these events may be obtained on the VA website (http://www.cqp.med.va.gov/cpq/cpg.htm) or from the DOD site (http://www.cs.amedd.army.mil/qmo).

9.4.3 Transportation

In some situations other agencies will wish to conduct the damage assessment, and WSDOT may be tasked to provide aerial transportation.

WSDOT may be tasked to gather intelligence during emergencies or disasters. Examples of intelligence activities include:

- Signals intelligence. Aircrews should report any unusual radio communications overheard during sorties.
- Human intelligence. Aircrews returning from sorties will be debriefed on operating conditions, notable changes to infrastructure and terrain, and the condition of local infrastructure.
- Imagery intelligence. All aircrews should be equipped with digital cameras, camcorders, instant-film cameras or film cameras for use in recording conditions encountered during operations. Slow-Scan or similar real-time video imagery will also be used. Camcorders are best for large-scale disasters because continuous filming allows coverage of multiple targets and allows for audio comments during filming. Digital cameras are of great value because they allow you to immediately see the results of your shot and they allow for the images to be quickly and widely disseminated.

NOTE: If an aircrew observes unidentifiable, suspicious, or hostile traffic (land, aerospace or sea borne) which, because of its nature, course, or actions, could be considered a threat to the security of the United States or Canada, they will *immediately* inform mission base.

9.4.4 Damage assessment

Flying damage assessment sorties is not much different than flying search patterns. The big difference between a search for a downed aircraft and damage assessment is *what you look for* in the disaster area. The best way to discuss this is to look at the kinds of questions you be asking yourselves during your sortie.

Most often you will be given specific tasking for each sortie. However, you must always be observant and flexible. Just because you have been sent to determine the condition of a levy doesn't mean you ignore everything else you see on the way to and from the levy.

Different types of emergencies or disasters will prompt different assessment needs, as will the nature of the operations undertaken. Examples of questions you should be asking are (but are certainly not limited to):

- What is the geographical extent of the affected area?
- What is the severity of the damage?
- Is the damage spreading? If so, how far and how fast? It is particularly important to report the direction and speed of plumes (e.g., smoke or chemical).
- How has access to or egress from important areas been affected? For example, you may see that the southern road leading to a hospital has been blocked, but emergency vehicles can get to the hospital using an easterly approach.

- What are the primary active hazards in the area? Are there secondary hazards? For example, in a flood the water is the primary hazard; if the water is flowing through an industrial zone then chemical spills and fumes may be secondary hazards.
- Is the disaster spreading toward emergency or disaster operating bases, or indirectly threatening these areas? For example, is the only road leading to an isolated aid station about to be flooded?
- Have utilities been affected by the emergency or disaster? Look for effects on power transmission lines, power generating stations or substations, and water or sewage treatment facilities.
- Can you see alternatives to problems? Examples are alternate roads, alternate areas to construct aid stations, alternate landing zones, and locations of areas and facilities unaffected by the emergency or disaster.

While it is difficult to assess many types of damage from the air, general aviation is well suited for preliminary damage assessment of large areas. Generally, you will be looking to find areas or structures with serious damage in order to direct emergency resources to these locations.

A good tool for assessing tornado damage is "A Guide to F-Scale Damage Assessment" (U.S. Department of Commerce, NOAA, NWS; it can be downloaded from the web as a .pdf file).

It is very important to have local maps on which you can indicate damaged areas, as it is difficult to record the boundaries of large areas using lat/long coordinates.

Air assets can quickly provide vital information on the status of:

- Transportation routes (road and rail).
- Critical facilities/structures such as power stations, hospitals, fire stations, airports, water supplies, dams and bridges.
- Levees and other flood control structures.
- The type and location of areas that have been damaged or isolated.
- Concentrations of survivors (people and animals).

As discussed above, there are many things to look for during your sortie. Some specific things to look for are:

- Breaks in pavement, railways, bridges, dams, levees, pipelines, runways, and structures.
- Roads/streets blocked by water, debris or landslide. Same for helipads and runways.
- Downed power lines.
- Ruptured water lines (this may have a major impact on firefighting capabilities).
- Motorists in distress or major accidents.
- Alternate routes for emergency vehicles or evacuation.
- Distress signals from survivors.

NOTE: Local units should become proficient in identifying their neighborhoods, major facilities, and roads/streets from the air.

At each site, besides sketching or highlighting the extent of the damage on local maps and identifying access/egress routes, you should record:

- Lat/long.
- Description.
- Type and extent of damage.
- Photo number or time reference for videotape.
- Status (e.g., the fire is out, the fire is spreading to the northeast, or the floodwaters are receding).

After the sortie, remember to replenish your supplies and recharge batteries.

9.5 Missing Person Search

An individual is very difficult to spot from the air, but aircraft can do well in some situations:

- Persons who are simply lost and are able to assist in their rescue. Persons who frequent the outdoors are often trained in survival and have the means to signal searching aircraft.
- Persons who may be wandering along roads or highways, such as Alzheimer's patients.
- Persons trapped or isolated by natural disasters such as floods. These persons often can be found on high ground, on top of structures, along a road or riverbank.
- Persons who were driving. Their vehicle may be stopped along a road or highway.

Lost children and people with diminished capacities can be especially difficult to find. By the time WSDOT Aviation is called the police have probably already looked in the obvious places. Often, these individuals will be hiding from their searchers. Route and grid searches must be done with great care and with full, well-rested crews. Knowledge of what they are wearing and how they may respond to over-flying aircraft is especially valuable in these instances.

Lost persons often fight topography and are likely to be found in the most rugged portion of the surrounding country (persons who follow natural routes are seldom lost for long periods). Children under five years old frequently travel uphill; they also may hide from searchers (except at night).

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Chapter

10

10. Electronic Search Patterns

While the mission observer's role seems to be concentrated in visual searches, her contributions in electronic searches are no less important. The observer's understanding of electronic search techniques, and her ability to assist the pilot, can substantially increase both search effectiveness and the timeliness of recovering accident victims.

Electronic searches are most efficient when the equipment, the environment and the terrain are ideal. This includes flat, level terrain, few natural or man-made obstructions and properly functioning equipment. These ideals seldom exist. Therefore, the effectiveness of electronic searches depends heavily on the experience and expertise of the search crews employing them. Through practice, you will understand the difficulties caused by Emergency Locator Transmitter (ELT) signals reflected from obstructions, the adaptability of electronic search methods to overall conditions, and the monitoring of radio equipment to ensure proper operation.

The use of electronic equipment in locating missing aircraft or survivors is an alternative to visual searches. The primary equipment in these type searches is an ELT and an ELT reception device. Once it has been established that an ELT was on board the missing aircraft, a combined track route and ELT search can be launched. The success of this type of search depends on the life of the battery of the ELT, the survivability of the entire ELT unit and whether the unit was activated or not. There is always the possibility ELT equipment may be inoperable due to the effects of the crash. Since an ELT aboard an aircraft does not guarantee that it can be located with an electronic search, both an electronic search and a concentrated general search should be organized at the same time.

OBJECTIVES:

1. Discuss the various types of ELTs.
2. Describe how an ELT can be detected.
3. Describe how the aircraft DF works in both the Alarm and DF modes.
4. Discuss using the DF during a typical ELT search. Include how the DF should respond during the initial phase (including signal fade), when you are getting close, and when you pass over the beacon.
5. Describe the following ELT search methods: homing, wing null, aural search, and signal search.
6. Discuss signal reflection and interference.
7. Describe how to silence an ELT and the legal issues involved.

10.1 ELTs and SARSAT

Electronic equipment and procedures are used in general searches to focus the search and rescue effort in a specific area, or as an alternative to visual searches when visibility is reduced by weather or other atmospheric conditions. Equipment used in these searches may include a battery-powered emergency locator transmitter (ELT) aboard the incident aircraft, search and rescue satellites, and an ELT receiver aboard the search aircraft.

10.1.1 ELTs

The Federal Aviation Administration (FAA) requires most U.S.-registered aircraft to have operable ELTs installed, which activate automatically when sensing acceleration forces during an accident. An active ELT transmits a continuous radio signal on a specific frequency until it's either deactivated or its battery discharges.

Most general aviation aircraft have ELTs that transmit on 121.5 MHz at 60-100 milliwatts (less power than a small flashlight). They are activated by G-forces or by manual operation of a switch (some aircraft have a remote switch in the cockpit). **Space-based monitoring of 121.5 MHz is expected to cease on 1 FEB 09**.

Advanced ELTs that transmit on 406.025 MHz at 25 milliwatts are specifically designed to operate with the Cospas-Sarsat satellite system, and transmit data that contains a unique identifier number that links them to a database containing information on the vessel or aircraft and emergency points of contact. Some advanced 406 MHz beacons also transmit GPS information.

Military Beacons (e.g., URT-33/C) operate on 243 MHz. Personnel ejecting/parachuting from a military aircraft have this beacon; some pilots may be able to communicate via two-way radio on 243 MHz using a PRC-90 or later military survival radio (this radio also has a beacon mode).

Marine Emergency Position Indicating Radio Beacons (EPIRB's) are primarily found on boats and ships. Similar to ELTs, some are automatically activated while others can only be activated manually.

Personal Emergency Transmitters (PET's) are currently illegal for general use in the U.S. Personal Locator Beacons are now legal in the 48 continuous states. AFRCC requested that the 406 MHz PLBs rules become effective on July 1, 2003, which would allow AFRCC, NOAA and state agencies time to coordinate the transfer of distress alerts to responsible state agencies.

Practice beacons used by WSDOT transmit on 121.775 MHz. **Avoid calling the practice beacon an "ELT" while communicating on the radio; this can cause confusion.** The term "practice beacon" is very clear to all concerned and should be used on all drills and exercises.

ELT's can (and are) be inadvertently activated. Typical causes are excessively hard landings (Welcome aboard, Ensign!), inadvertent manual activation (e.g., removal/installation), malfunctions, or Monsieur Murphy. Also, non-ELT sources can transmit on 121.5 or 243 MHz; examples are computers, broadcast stations, and even pizza ovens.

Approximately 97% of all received ELT signals turn out to be false alarms. For 121.5 MHz ELTs only 1 in 1000 signals is an actual emergency! False alarms cause problems because SARSAT can only monitor 10 ELT signals at a time and because they block the emergency frequencies (thus blocking a real emergency signal). However, you must always treat an ELT signal as an emergency because you can't know whether the signal is real or false. Additionally, ELT missions keep your skills sharp.

10.1.2 SARSAT/COSPAS

In a cooperative effort among several nations, search and rescue-dedicated satellites (SARSAT and COSPAS) orbit the earth and alert to ELT transmissions. Upon receiving an ELT signal, the SARSAT derives the approximate lat/long coordinates of the ELTs position, and the coordinates are passed through the Air Force Rescue Coordination Center (AFRCC) to the incident commander.

WSDOT will not launch a search until the signal is picked up by at least two satellites. Also, system accuracy in pinpointing the location varies. For a typical 121.5 MHz ELT, accuracy is limited to a 15 nm radius (452 square nm); a 406 MHZ ELT can be narrowed down to a 3 nm radius (12.5 square nm) and one with GPS can be narrowed down to a 0.05 nm radius (0.008 square nm).

Upon receiving SARSAT coordinates, or determining that an ELT was aboard a missing aircraft, the incident commander may launch a combined ELT/visual route search. Search success may depend upon several factors. The fact that an ELT was aboard a missing aircraft does not necessarily guarantee that electronic search procedures will locate it because the unit may have been inoperative or the batteries totally discharged. Also, the crash forces may have been insufficient to activate the ELT or so severe that it was damaged. Incident commanders may attempt to maximize the search effort by conducting an electronic search and a general visual search simultaneously when weather and other circumstances permit.

10.2 Locating the ELT Signal

Before you can use any technique to locate an ELT, you must first be able to pick it up on your radio. The route (track line) pattern (Figure 10-1) or the parallel track (Figure 10-2) search patterns are the most effective at this stage. The aircraft conducting an electronic search will normally begin the search at or near the last known position (LKP) and fly the search pattern at altitudes from 4,000 to 10,000 feet above the terrain if possible. At this altitude, the aircraft can usually intercept the ELT signal, as well as recognize or distinguish the downed aircraft. At the maximum electronic search altitude, which is much higher than 10,000 feet, chances are slim that one can recognize or distinguish a light plane crash site. Maximum track spacing should be used initially to provide a rapid sweep of the probability area. Successive sweeps should have a track spacing one-half the size of the initial spacing. For example, if the track spacing is 60 nautical miles during the initial sweep of the area, then the track spacing for the second sweep of the area should be 30 nautical miles. A third sweep of the area, if needed, should have track spacing of 15 nautical miles. This method of gauging the track spacing applies to both track line (route) and the parallel track. These procedures may be repeated until the missing aircraft or survivors are located, or until it is presumed that the batteries of the ELT have been exhausted.

In mountainous terrain the initial search pattern should be arranged to cross the ridgelines at right angles, if at all possible. The search coverage of the area should be at right angles to the first coverage tracks to compensate for blockage of the ELT signal due to the shape of the terrain.

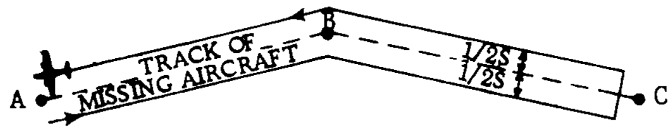

Figure 10-1

Once the searchers are in a position to receive the ELT signal, they may use one of several methods to locate the transmitter and the accident scene. Homing is the simplest and most common method, but it requires special equipment that is not be installed in all search airplanes. The metered search also requires special equipment that may not always be available. The signal-null and aural search methods are used less frequently, but they may be used aboard any airplane equipped with a radio receiver. Each requires only the crew's ability to hear the ELT tone through the search aircraft's radio or intercom.

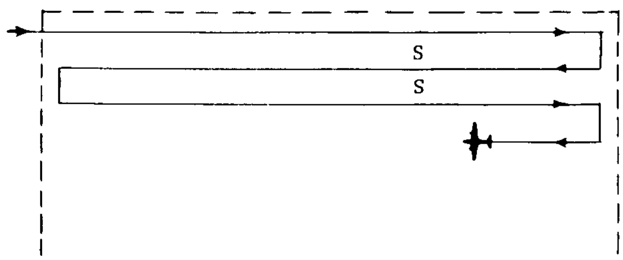

Figure 10-2

10.3 Aircraft Direction Finder (DF)

The L-Tronics LA series Aircraft Direction Finder, the most common DR unit found in Search aircraft, consists of VHF and UHF receivers, two- or three-element yagi antennas and circuitry. The controls consist of a frequency selector switch, an alarm toggle switch (works like a light switch), and a dual-knob control switch for volume (inner knob) and sensitivity (outer knob). There are two indications: a DF meter and a signal Strength meter (refer to Figure 10-3).

Figure 10-3

The tone-coded squelch circuit, called the Alarm mode, permits continuous, annoyance-free monitoring for Emergency Locator Transmitters (ELTs) and Emergency Position Indicating Radio Beacons (EPIRB's) on 121.5 MHz.

The DF unit is normally connected to the aircraft audio system. This connection allows an audible as well as a visual alarm when an ELT signal is detected in ALARM mode.

The three-whip antenna array provides for dual band operation. The performance of the DF is absolutely dependent on the antenna installation. The whip antennas and the aircraft structure work together to form the directive antenna patterns necessary to the operation of the DF set.

There is considerable interaction between DF and Comm antennas. The DF switching may put a strong tone on communications receiver signals from some directions. The DF may have to be turned off or the aircraft heading changed for good Comm intelligibility. In particular, the DF receiver may cause interference to communications on 132.3 MHz when operating on 121.5 MHz (126.85 MHz when using 243.0 MHz).

10.3.1 Normal Operations and Checks

The Alarm mode is the normal mode for routine conditions. It enables the pilot to monitor the emergency frequency (121.5 MHz) without dedicating a communications radio to the task. DO NOT USE THIS MODE DURING A DF SEARCH because the DF function is disabled in the Alarm mode.

To select the Alarm mode, place the Alarm toggle switch on (up). Set the **SENS**itivity so that the needle just comes on-scale and the **VOL**ume to a comfortable level (the ear will detect a weak signal far sooner than the alarm). [Note: The Alarm mode is designed to work with weak signals; if an ELT is transmitting nearby and the unit is set to full sensitivity, the receiver may overload.]

If an ELT activates the Alarm, turn the Alarm toggle switch off (down). This activates the DF function and allows you to track the signal.

The alarm unit automatically rejects false signals. The ELT signal must remain at sufficient strength for 5-20 seconds before the alarm light (flashing red LED) is activated.

<u>Functional Check - No transmitter</u>

This is a quick check that can be made part of a preflight routine to assure that a previously checked unit is still working:

- ❑ Select 121.5 MHz on the DF.
- ❑ Turn the Alarm toggle switch off (down).
- ❑ Turn the SENSitivity control (outer knob) fully clockwise to maximum.
- ❑ Turn on power to the radio system.
- ❑ Turn on the DF by advancing the VOLume control (inner knob).
- ❑ A hissing sound should be heard through the audio system and the signal strength needle will be between ¼ and ½ of the way between the center of the scale and the left-hand end. The DF needle will stay roughly centered.
- ❑ Now turn the SENSitivity control counterclockwise toward minimum. This will cause a decrease in sound volume (some sound may still be heard) and a decrease in the strength meter reading.
- ❑ Next, turn the SENSitivity control to maximum. The DF needle should move randomly back and forth one or two needle-widths about the center in response to receiver background noise. *Movement will be slow and may be difficult or impossible to see.*

- ❑ As a final check, turn the Alarm toggle switch to on (up). The Alarm light should flash for 10 to 20 seconds and then stop. The receiver noise should also cut off at the same time. The Alarm is now set and will respond to a steady ELT signal. *[NOTE: This Alarm setting period occurs each time the Alarm function of the DF is turned on. It tests the Alarm circuits and reminds the pilot that the DF receiver is on.]*

Functional Check - with transmitter and the aircraft on the ground

All features of the DF except the Alarm circuit can be checked using a practice beacon.

- ❑ Park the aircraft in the open, away from metal buildings. The transmitter should be at least 50 feet in front of and 15-30 degrees to one side of the aircraft.

WARNING: Use of high-power transmitters close to the DF antennae can damage the unit. Damage can occur from a 50-watt transmitter if it is within 12 feet of the antennae (3 feet for 5W; 4 1/2 feet for 10W; 15 feet for 80W). The ELT tester should be kept at least 50 feet away from the antennae when using to test for operability of the DF.

- ❑ Select 121.775 MHz on the DF.
- ❑ Rotate the SENSitivity control fully counterclockwise to minimum.
- ❑ Set the VOLume control to about the 12 o'clock position.
- ❑ Set the Alarm toggle switch off (down).
- ❑ Turn on the DF and the transmitter. If necessary, rotate the SENSitivity control clockwise until the signal or the DF buzz is heard.
- ❑ The DF needle should point toward the transmitter. Move the transmitter to the other side of the aircraft and observe the DF needle, which should follow the transmitter. NOTE: On the ground it is normal for the needle to be uncertain about centering with the test transmitter directly fore or aft. The DF is OK if the needle points correctly when the transmitter is on either side of the aircraft.
- ❑ Move the SENSitivity control clockwise. The strength needle will move (slowly) further to the right.

Functional Check - with transmitter and the aircraft in flight

- ❑ Place the practice beacon as high and clear as possible in open terrain.
- ❑ Fly about three to five miles away at 2000 to 3000 feet AGL.
- ❑ Make several full circles, starting with no more than a 10° bank-angle. The DF needle should crossover only twice during the turn at shallow bank. More than two crossings indicate unsatisfactory operation.
- ❑ Pilots and observers should note how the DF performs at steeper bank angles for future reference. Note also where wing shadows occur, as indicated by decreases in the strength meter reading and/or audio volume during steep turns. This is a useful verification of DF indications.
- ❑ Determine the direction to the practice beacon by turning in the direction of DF needle deflection.
- ❑ With the needle centered, follow the DF course inbound and compare it to the visual heading to the target transmitter.
- ❑ The inbound course and the heading to the transmitter should agree to +/- 5° (up to +/- 15° error is quite usable). If desired, you can note the error on a placard near the DF receiver.
- ❑ Finally, compare the inbound and the outbound courses using the DG (heading indicator). They should differ by 180°.
- ❑ Course errors of up to 30° are usually due to unsymmetrical installation of the antennas or, on the ground, to nearby reflecting objects (e.g., cars or buildings).

Asymmetry usually causes both front and rear courses to be bent toward the same side of the aircraft and usually toward the source of the problem.

- Severe errors or one-sided needle indications are usually due to a damaged antenna-to-switchbox cable or to poor grounding at the antenna or a skin joint nearby. Poor skin-joint contact may well indicate structurally significant corrosion and should be investigated by a mechanic.

NOTE: L-Tronics technical support can be reached at 805-967-4859 or www.ltronics.com

10.3.2 DF Operations

Verify or select 121.5 on the frequency switch and place the Alarm toggle switch to off (down). **The Alarm mode must not be used during a DF search because the DF function is not operable in the Alarm mode (toggle switch up).** Set the SENSitivity to maximum and the VOLume to a comfortable level.

Climb to an altitude of *at least* 3000 to 4000 feet AGL, if possible. Fly to the area of the reported ELT signal (but remember, an ELT search begins the minute you take off). If the ELT cannot be heard in the expected area, climb to a higher altitude. If this fails to acquire the signal, start a methodical search (e.g., area or expanding square).

Unless the beacon is known to be a 406 MHz EPIRB (which doesn't transmit on 243 MHz) or a military beacon (which uses 243 MHz and may also transmit on 121.5 MHz), switch between 121.5 and 243 MHz at least once each minute until a signal is heard. All civil beacons except 406 MHz EPIRB's and some military beacons transmit on both frequencies. Undamaged ELTs can usually be heard further on 121.5 MHz than they can on 243 MHz; the reverse is often true for damaged ELTs.

Initial Heading

When first heard, the ELT signal will probably be faint and will build slowly in strength over a period of several minutes. Continue flying until a reasonable level of signal is acquired. The DF needle should deflect to one side and the Strength needle should come on-scale. Resist the urge to turn immediately and follow the needle; instead, make a 360° turn at no more than a 30° bank to ensure you get two needle centerings (approximately 180° apart) to verify the heading. When the turn is complete, center the DF needle and fly toward the ELT. Note your heading (write it down) for reference.

If the ELT is heard on both 121.5 and 243.0 MHz, compare the headings. If they differ by more than 45° or if the turn produces multiple crossovers, try a new location or climb to a higher altitude to escape from the reflections.

While flying toward the ELT the DF needle may wander back and forth around center at 10- to 30-second intervals. This is caused by flying through weak reflections and should be ignored. Fly the heading that keeps needle swings about equal in number, left and right.

Signal Fade

Don't become concerned if the signal slowly fades out as you fly towards the ELT. If this happens, continue on your heading for at least six minutes. If you are still headed toward the ELT the signal should slowly build in strength in three or four minutes and be somewhat stronger than before the fade. If the signal does not reappear, return to where the signal was last heard and try a different altitude.

Getting Close

As you get close to the ELT the signal will get stronger, and you will have to periodically adjust the SENSitivity control to keep the signal strength needle centered (*do not* decrease the VOLume control as this could overload the receiver). You also need to do this if the DF needle gets too sensitive. Periodically yaw the aircraft and observe the DF needle respond (left and right).

Passing Over

A "station passage" is often seen as a rapid fluctuation in signal strength and confused DF readings. Yaw the aircraft to see if the course has reversed (needle goes in the direction of the aircraft turn). If the course has reversed, continue on your heading for a few minutes. Then turn and make several confirmation passages from different angles while continuing your visual search.

10.4 Homing Method

Homing is an electronic search method that uses a direction finder to track the ELT signal to its source. Tune the direction finder (DF) to the ELT operating frequency; the pilot will fly the aircraft to the transmitter by keeping the left/right needle centered. ELT's may transmit on either 121.5 MHz VHF, 243.0 MHz UHF, or both frequencies simultaneously. These emergency frequencies are *usually* the ones monitored during a search, but homing procedures can be used on any radio frequency to which *both* a transmitter and DF receiver can be tuned.

In the following scenario, the search objective is an active ELT at a crash site. The first step is to tune the receiver to the ELT frequency and listen for the warbling tone of the ELT signal. Next you have to determine the direction to the ELT. When you fly directly toward a signal, the left/right needle remains centered. However, when you head directly *away* from the signal, the needle also centers. A simple, quick maneuver is used to determine if you are going toward or away from the signal.

Starting with the left/right needle centered, the pilot turns the aircraft in either direction so that the needle moves away from center. If he turns left, and the needle deflects to the right, the ELT is in front. If the pilot turns back to the right to center the needle, and then maintains the needle in the center, you will eventually fly to the ELT.

If, in the verification turn, the pilot turns left and the needle swings to the extreme left, then the ELT is behind you. Continue the left turn until the needle returns to the center. You are now heading toward the ELT, and as long as the pilot maintains the needle in the center, you will fly to the ELT.

Flying toward the ELT, maintaining the needle in the center of the indicator *is* the actual homing process. If the needle starts to drift left of center, steer slightly left to bring the needle back to the center. If it starts to drift right, turn slightly back to the right. Once you have completed the direction-verification turn, you will not need large steering corrections to keep the needle in the center.

When passing over the ELT or transmission source, the left/right needle will indicate a *strong* crossover pattern. The needle will make a distinct left-to-right or right-to-left movement and then return to the center. This crossover movement is *not* a mere fluctuation; the needle swings fully, from one side of the indicator to the other and then returns to the center.

During homing you may encounter situations where the needle *suddenly* drifts to one side then returns to center. If the heading has been steady, and the needle previously centered, such a fluctuation may have been caused by a signal from a second transmitter. Another aircraft nearby can also cause momentary needle fluctuations that you might not hear, but the needle in the DF will react to it. Signal reflections from objects or high terrain can also cause needle fluctuations at low altitudes in mountainous terrain or near metropolitan areas.

10.5 Wing shadow method (signal null)

The signal null or wing shadow method is based on the assumption that the metal skin of the search aircraft's wing and fuselage will block incoming ELT signals from the receiving antenna during steep-banked turns. The observer can make simple estimates of the magnetic bearing to the transmitter by checking the aircraft heading when the signal is blocked.

Once the search aircraft completes several signal-blocking turns in different sectors of the search area, the observer can establish the approximate location of the ELT by drawing magnetic bearings, or "null vectors," on the sectional chart. The ELT and accident scene will be at or near the intersection of the null vectors.

To use the null method, you must know the location of your receiving antenna. On a low-wing airplane, like the Piper *Cherokee,* the Comm antenna is often mounted on the underside of the fuselage, in line with the wings. On a high-wing airplane, like the Cessna 172, the Comm antenna is normally mounted on the top of the airplane, again in line with the wings. [Note: You may also use the receiver of your aircraft's DF unit, which is normally mounted on the bottom of the aircraft.]

10.5.1 Procedures

First, verify the receiver is tuned to the proper ELT frequency and that you can hear the warbling tone. Mark your position on the sectional chart, preferably over a small but significant feature. Then the pilot will make a 360° steeply banked turn to allow you to determine the signal's direction. As the airplane turns, the ELT tone will break, or null, at the point when the aircraft wing and skin come between the transmitter and the antenna. For a brief instant you will not hear the tone. The absence of the audible tone is referred to as the *null*.

On low-wing aircraft with the antenna installed on the underside, the wing inside the turn, or the "down" wing of the banking airplane, points toward the ELT when the tone nulls. On high-wing aircraft, with the antenna installed on the top surface, the wing on the outside of the turn, the "up" wing, points toward the ELT when the null is heard.

To estimate the magnetic bearing from the search airplane to the ELT, the observer makes simple calculations. In high-wing airplanes, if you're turning left, add 90° to the aircraft heading when you hear the tone null. If you're turning right, subtract 90° from the heading at the instant you hear the tone null. In low-wing airplanes, when you're turning left, subtract 90° from the aircraft heading, and when making right turns, add 90° to aircraft heading.

You may find it simpler to make these bearing estimates using the face of the Heading Indicator. Imagine an aircraft silhouette on the face of the HI: the silhouette's nose points up toward the twelve o'clock position, and the tail points toward the bottom or six o'clock position. The left wing points left to nine o'clock, and the right wing points to three o'clock. Some heading indicators actually have this silhouette painted on the instrument face, as shown in Figures 10-4 and 10-5. This imaginary plane always mimics whatever the search airplane is really doing.

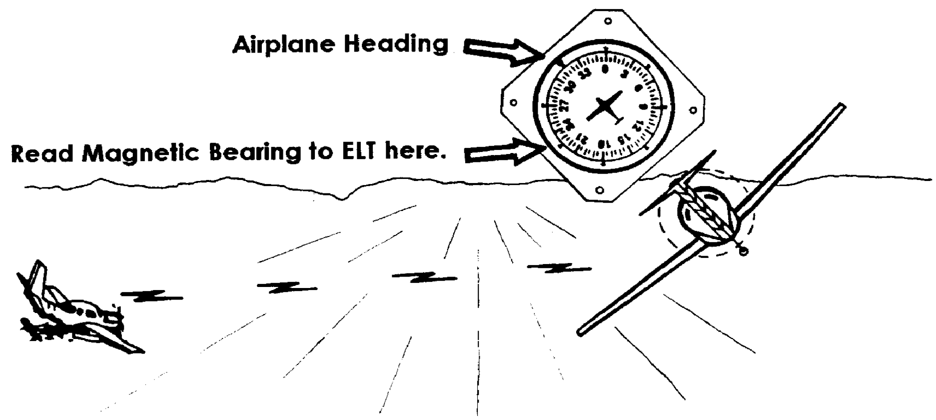

Figure 10-4

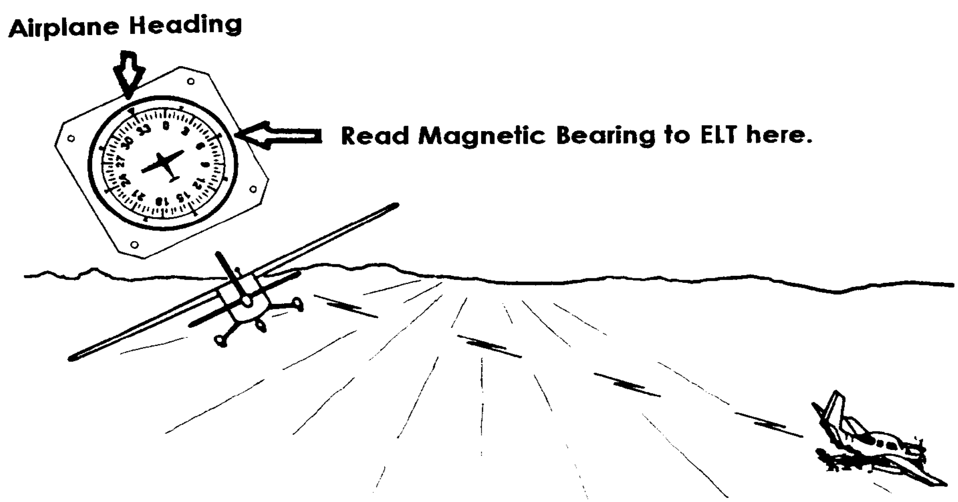

Figure 10-5

Upon hearing the null, the observer should quickly look at the heading indicator. If the search aircraft is a low-wing aircraft, like the *Cherokee,* look for the number adjacent to the imaginary aircraft's low wing, as shown in Figure 10-4. If the search plane is a high-wing, like the Cessna 172, look for the number adjacent to the imaginary plane's high wing, as shown in Figure 10-5. That number is the magnetic bearing from the search aircraft's present position to the ELT transmitter.

Regardless of the method used to determine the ELT's magnetic bearing, the next step is to convert that magnetic bearing to a true bearing by adding or subtracting the published magnetic variation for that area. Then draw a line on your chart from the search aircraft's known position in the direction of the calculated true bearing. You now have one null vector, or line of position, to the

ELT. The ELT is somewhere along that line, but it isn't possible to tell exactly where. To narrow the focus, simply repeat the process starting from another known position over a different geographical point. Don't pick your next geographical point near to or along the initial null vector. The accuracy of this technique improves if you select geographic points well away from each other. If the points are well separated, the null vector lines will intersect at a larger angle, and the position will be more accurate.

Figure 10-6 shows an entire null signal search. Notice that several fixes may be taken before deciding the limits for the subsequent visual search. Finally, fly to the area indicated by the null-vector intersection and attempt to pinpoint the ELT.

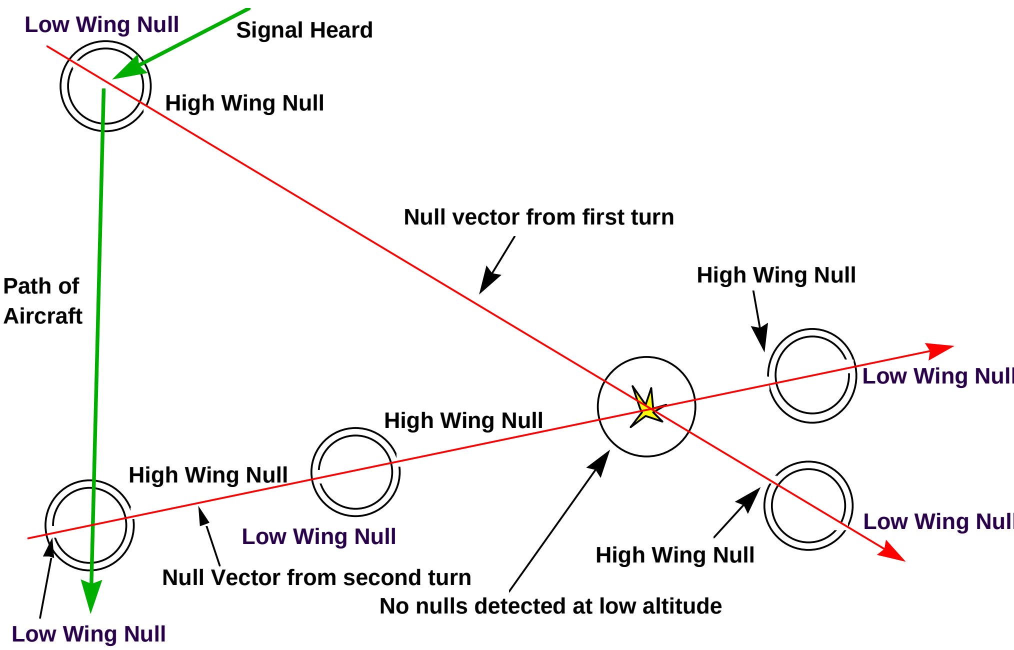

Figure 10-6

Upon reaching the area, the pilot can descend to a lower altitude and execute similar steep turns. If you are very close to the ELT, you can expect to hear no null, due to the higher signal strength near the transmitter and the inability of the wing to block the signal. When an ELT tone is continuous through a full 360° turn, the ELT transmission is very likely in the area beneath the search aircraft. You can then chart the probable location of the missing aircraft or transmitter to within a small area.

If descending to a lower altitude brings the aircraft within 1,000-2,000 feet above the terrain, you should discontinue null procedures. Instead, you should descend to an appropriate lower altitude and begin a visual search.

10.5.2 Special Considerations in Wing Null Searches

Four special considerations must be made prior to and during wing null searches. The most important is crew ability. Maintaining altitude throughout steep turns requires skill and extensive practice. Some aircraft may stall and then spin if over-controlled in poorly executed turns. This can result in a great loss of altitude, structural damage to the airplane during recovery, or collision with the ground. The pilot must be skilled in executing steep-banked turns.

Second is positive knowledge by the search crew of its actual position when the null is heard. By constantly monitoring the search aircraft's position in the turn, you can plot each null vector more precisely.

Third, the search crew must know what to do if the signal is lost during a search. If you lose the signal while trying to pinpoint the ELT's location, you can return to the position and altitude of the last contact with the tone. The observer's chart is a useful record of each position where successful procedures were performed.

Finally, as you approach the suspected ELT location, be more alert for other aircraft. Since a search is likely to include more than just your airplane, you should expect the ELT location to become a point of convergence for all aircraft involved in the search. Once you establish the general location of the downed aircraft, you *must* approach the area with caution. A midair collision can easily result if the entire crew's attention is focused on the accident scene while other aircraft approach the same area.

10.6 Aural (or hearing) search

The aural or hearing search technique is based on an assumption that an ELT's area of apparent equal signal strength is circular. Throughout this procedure the observer *must not* adjust the receiver volume. A constant volume helps assure that "signal heard" and "signal fade" positions will remain consistent. Also, once you begin the procedure, make all turns in the same direction as the first turn if terrain permits. When using this procedure, which does not require a special antenna, the search aircraft is flown in a "boxing in" pattern.

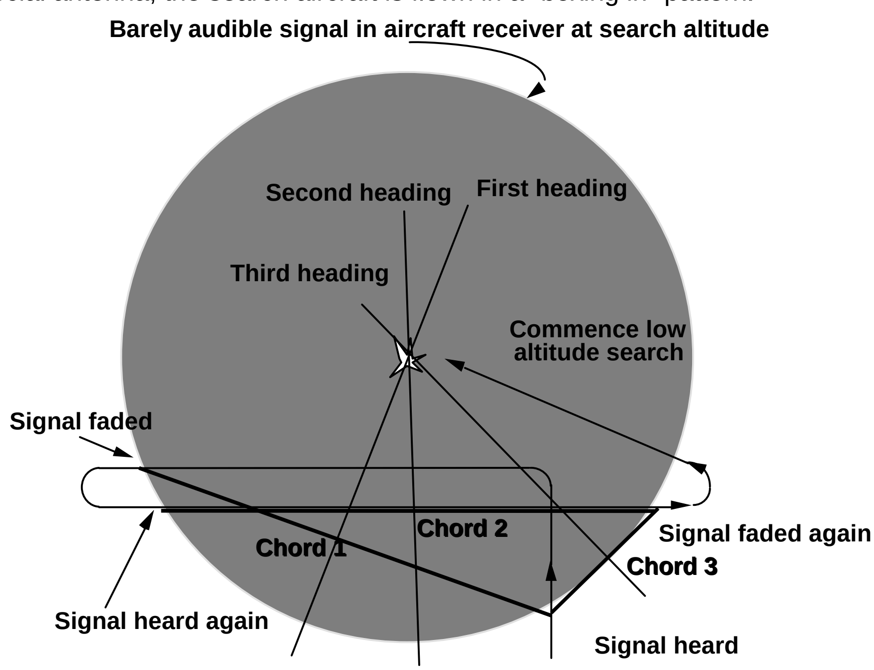

Figure 10-7

The observer begins the aural search by plotting the search plane's position when the ELT tone is first heard. The pilot continues flying in the same direction for a short distance, then turns 90° left or right and proceeds until the tone volume fades. The observer charts the aircraft position where the tone volume fades. The pilot then reverses aircraft direction, and the observer again marks on the map the positions where the signal is heard again and where it fades. If the radio volume has not been adjusted, the "signal fades" and "signal heard" positions should be approximately equidistant from the ELT. To determine the approximate location of the ELT, the observer draws lines to connect each set of "signal heard" and "signal fade" positions.

To establish the approximate position of the ELT unit, the observer draws chord lines between each set of "signal heard" and "signal fade" positions. Then the observer draws perpendicular bisectors on each chord. The bisectors are drawn from the mid-point of each chord toward the center of the search area. The point where the perpendicular bisectors meet, or intersect, is the approximate location of the ELT unit (Figure 10-7 illustrates the connection of the signal heard and signal fade positions with the chord lines, the perpendicular bisectors' converging toward the center of the search area, and the intersection over the probable location of the ELT). After the observer establishes the approximate location where the missing aircraft may be found, the pilot flies to that location and begins a low-altitude visual search pattern. [Note: The perpendicular bisectors rarely intersect directly over the objective. However, a low-altitude visual search of the general area can help compensate for lack of precise location.]

10.7 Metered search

To employ the metered search method, the observer uses a signal strength meter to monitor the ELT signal (Figure 10-8). Circled numbers represent the sequence of events: numbers plotted along the track are hypothetical signal meter readings with higher numbers representing weaker signals and lower numbers representing stronger signals.

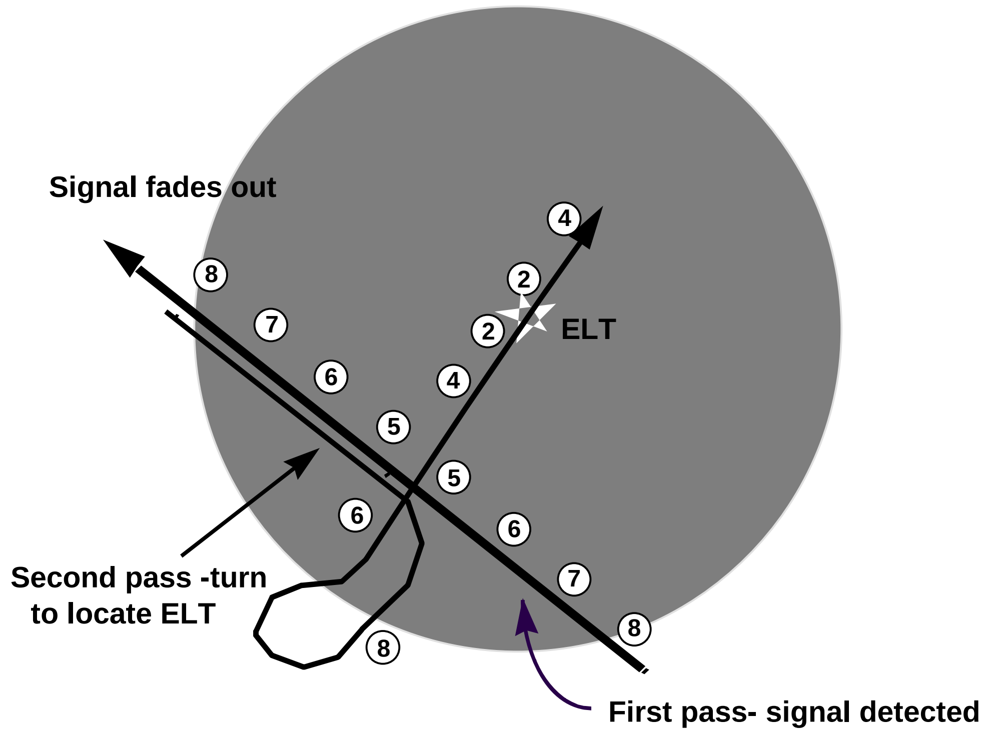

Figure 10-8

Once the aircraft enters the search area, the observer plots two positions of equal meter strength. The observer records the first ELT signal strength (assume the signal strength measures 8.0) and plots the search aircraft's position on the chart. The pilot continues flying the aircraft in the same direction and the signal strength will first increase, then decrease. When the signal strength returns to the previous value (8.0), the observer plots the aircraft's position. The observer now plots the midpoint between these two points, while the pilot reverses direction and flies back toward that midpoint. Upon reaching the midpoint, the pilot makes a 90° turn to the right or left. If signal strength begins to fade, the search aircraft is heading in the wrong direction and the pilot corrects by reversing direction. This last change now carries the search aircraft toward the ELT. The search crew then begins a visual search at an appropriate altitude.

10.8 Night and IFR electronic search

Each of the preceding electronic search methods has certain limitations that affect its usefulness during darkness or in instrument conditions. In this discussion, “instrument meteorological conditions” (IMC) means weather conditions that compel the pilot and crew to operate and navigate the aircraft by referencing onboard instruments and navigational radios.

10.8.1 Night ELT searches

Darkness eliminates your ability to precisely determine your position in reference to the ground, and that impacts the effectiveness of your search. Once you've successfully homed to an ELT you can usually narrow the target area down to about one square mile. Unless the ELT is located on an airfield or the occupants of the target aircraft are able to signal you, you will have to call in a ground team or land at the nearest airport, arrange for transportation, and find the ELT with hand-held equipment.

If you have a GPS that will plot your flown track, you can pinpoint the ELT's position more accurately. After station passage is assured, fly another two minutes. Make a 90° turn (either way) and fly for another five minutes. From this point, DF back to the ELT and repeat the process, making turns in the same direction. When you look at the plotted track on the GPS, the lines will cross at a point over the ELT. You can then read off a lat/long position from the GPS, which is usually good to better than 1/2 mile - certainly good enough to get a ground crew headed to the right place. This technique can also be used in IMC.

10.8.2 IMC ELT searches

It is possible to DF in IMC, but this is dangerous and not to be undertaken lightly. Instrument flight imposes a higher workload on the pilot and demands a higher level of training and proficiency. As discussed earlier, the ability to fly steep-banked turns and other maneuvers without losing altitude is demanding for even the most proficient pilot. Trying to conduct these maneuvers while flying solely by referencing the flight instruments is not wise; the pilot can easily get vertigo and lose control of the aircraft.

For these reasons only highly trained and proficient pilots should attempt to DF in IMC, and it is highly recommended that another equally proficient instrument-rated pilot fly in the right seat.

10.9 Signal Reflection and Interference

Radio signals reflect off terrain and manmade objects, and this can be a problem for search and rescue teams. In an electronic search, it is vitally important to know if the equipment is reacting to reflected signals and what you can do to overcome the problem. Although tracking a signal is the best means of locating an ELT, actually isolating the signal can occasionally become a problem. The following scenario illustrates one approach to a signal reflection problem.

After receiving a briefing, the pilot and observer check their aircraft and take off. Upon reaching the designated search area, the observer picks up an ELT signal. Using the DF, the search crew follows the signal for 10 minutes in a northerly direction. The observer later notes that keeping the left/right needle centered requires a 60° turn. This sudden turn causes the observer to conclude the signal is being reflected for two reasons. First, it is highly unlikely that the aircraft wreckage moved, causing a change in direction. Second, if sufficient crosswind was present to cause the change, it should have been noticeable earlier. Since the wreck didn't move, and there is no significant crosswind, the observer concluded that the apparent course problem was caused by reflected signals.

The observer can have the pilot climb to a higher altitude to eliminate or minimize the effects of reflected signals. Reflected signals are usually weaker (lower signal strength) than those coming directly from the transmitter, so climbing can help the stronger direct signals come through. Also, depending on the terrain, a higher altitude may result in more time available for the crew to detect the transmitter. Figure 10-8 shows how climbing to a higher altitude can help overcome the problem of signals blocked by terrain.

NOTE: You can take advantage of the fact that reflected signals are generally weaker by tuning your radios further away from the primary frequency (signal-offset). Assume the ELT is transmitting on 121.5; one radio will be tuned to this frequency and the other will be set to 121.55. You toggle back and forth between the two frequencies as you approach the suspected location until you hear a signal on 121.55. As you home in on the target make 121.55 the primary and set 121.6 on the other radio and repeat the process (you may even work up to 121.7). As you get further away from the initial frequency the area where the signal will break through the squelch becomes smaller and smaller (you can even turn up the squelch to get further isolation). This method also works well from the ground.

The specific pattern used during an electronic search over mountainous or hilly terrain can help compensate for blocked signals and reflections. You should alternate flying patterns parallel to valleys or ridges, and flying the patterns at perpendicular angles. The following example (Figure 10-9) demonstrates this technique.

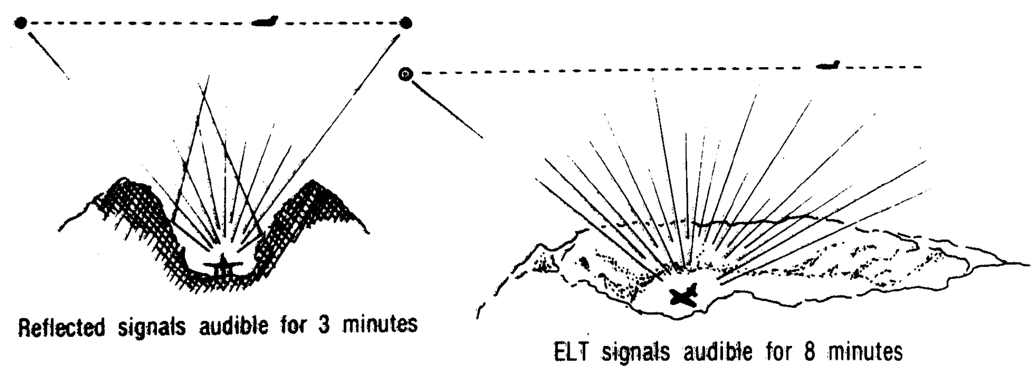

Figure 10-9

The crew receives the briefing and flies to its assigned area. A range of mountains extending north to south divides the rectangular-shaped area. The search crew elects to fly the initial pattern over the area east to west, and then returns west to east. After making 5 uneventful passes over the mountains 10,000 feet above the terrain, the observer hears the ELT on the sixth pass. On subsequent passes the observer hears the signal for three minutes during each pass and plots each area where the signal was audible. To further define the ELT position, the observer requests the pilot fly a course perpendicular to the previous headings. This new course takes the aircraft parallel to the mountain range. On the third pass near the mountains, the observer hears the ELT again, this time for eight minutes. After another pass over the area to verify the eight-minute reception, the observer plots a small area on the map as a likely location of the ELT. The observer concludes that terrain is a major factor in causing the signal to be audible for short periods of time. The missing aircraft has possibly crashed in a ravine or narrow canyon that permits transmission of the ELT signals to a limited area above the crash site.

Descent to a lower altitude helps confirm the observer's speculation. The missing aircraft has crashed in a long, narrow ravine running parallel to the north-south mountain range. The mountain walls around the aircraft significantly limit transmission of the signals in an east-west direction, so the observer is only able to hear the signal for three minutes while searching in an east-to-west or west-to-east direction. When the aircraft track is parallel to the mountain range, the observer hears the signal for eight minutes. When the crew flies along the length of the ravine where the plane crashed, they are able to maintain signal contact for a longer time.

When faced with strange circumstances like the two examples described above, try to visualize the situation and search for a logical explanation. Consider every factor that could cause the problem, including equipment reliability, terrain, other sources of interference like the electrical fields of high-tension power transmission lines, and the direction finding procedures themselves. If one method of electronic search doesn't yield the results you expect, try another method. Don't become so involved with one method that you can't switch to a more suitable method if the situation demands.

NOTE: If a signal is *only* received on 243 MHz, it *may* be a malfunctioning antenna (e.g., an FAA tower). If you DF to the location (particularly on or near an airport) and you keep ending up at an antenna, investigate. Find out who owns the antenna and its purpose. Inform the IC and let the controlling agency troubleshoot the problem.

Electronic searches are normally only as effective as the crews employing them. They work best when the equipment, environment, and terrain are ideal. Unfortunately, such ideal conditions seldom exist. Crews must practice search methods to better understand difficulties caused by various conditions. This will help them be prepared to deal with less than ideal conditions. Whenever you are faced with strange circumstances, you should seek the most logical explanation. In looking at the problem, always consider every factor that could possibly cause the situation. Consider the equipment reliability, the terrain and the DF procedures. If one method of electronic search doesn't yield the type of results you expect, try another method. Don't become so involved in one method that you can't adopt a more suitable method if the situation demands it.

NOTE: The newest Direction Finder, the *Becker SAR-DF 517*, is in limited use and so is not covered at this time. Information on this unit can be found in Attachment 2 and at www.becker-avionics.com

10.10 Silencing an ELT

If you don't have a ground crew and you have determined the ELT signal is coming from (or very near) an airfield, you will have to land and find the offending transmitter. You can use a hand-held DF unit (Little L-Per or Tracker) and/or a hand-held radio to locate the beacon.

Sometimes you locate the hangar and find it is full of aircraft. Two methods are very useful in narrowing down the search: the signal-offset method was discussed in section 10.9; another way is to use a hand-held radio. Hold the radio by one of the suspect aircraft (its ELT antenna, if mounted on the exterior) and turn the volume down until you can just hear the signal, then move to the next suspect aircraft and repeat. If the signal is stronger you probably have it; if it is weaker or cannot be heard it's probably the other aircraft. If needed, repeat with the radio's antenna removed (*Warning*: Do not key the radio's transmitter while it's antenna is removed!). [Note: You may also incorporate portions of the signal-offset method with this method.] Another technique is to slip an aluminum foil "sleeve" over the suspect ELT antenna while holding the radio by the antenna; if the signal fades significantly, you have found the signal.

Don't ignore the obvious: some aircraft have remote indicating lights (usually red) that flash when the ELT has activated; also look for obvious signs of disturbance near an ELT.

Once you have determined which aircraft the signal is coming from, you have to find the (physical) ELT. Most are located in the rear of the aircraft; also look for remote switches. The following gives some general locations:

- Single-engine Cessna: right side of the upper baggage area immediately aft of the baggage door.
- Multi-engine Cessna: left side of the fuselage just forward of the horizontal stabilizer. Accessed through a small push-plate on the side of the fuselage.
- Single- and multi-engine Piper: in the aft fuselage. Accessed through a small access plate on the right side of the fuselage (need a screwdriver).
- Single- and multi-engine Bonanza: in the aft fuselage. Accessed through a small access plate on the right side of the fuselage (need a screwdriver).
- Large turbine twins (e.g., King Air) or small jets: if installed its probably in the rear section. No visible antenna. May have a small round push-plate that gives you access to the switch with your finger.

The preferred method of silencing a transmitting ELT is to have the owner (or a person designated by the owner) turn it off and disconnect the battery; second best is just turning it off. Some owners will take the switch to OFF and then back to ARMED; monitor the emergency frequency for several minutes afterwards to ensure the ELT doesn't resume alarming.

If you cannot find the owner (or designee), you may have to install an aluminum foil 'tent' to limit the ELT signal range. Refer to Figure 10-10.

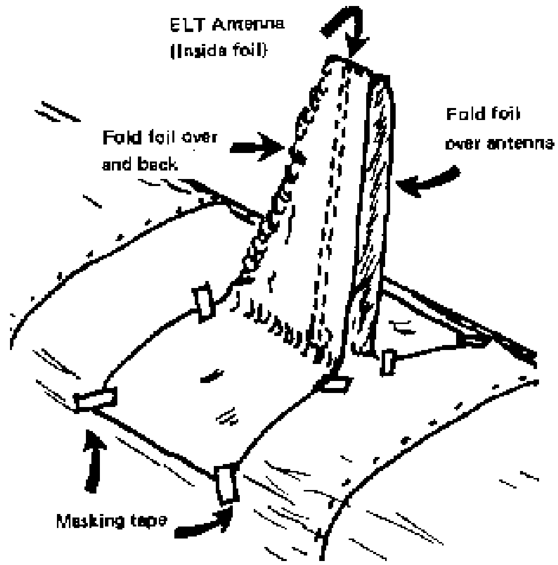

Figure 10-10

Take a piece of foil about one foot wide by about five feet long. Place the tip of the ELT antenna in the center of the foil and fold the foil down on both sides of the antenna. Let the ends lay flat against the fuselage; the flaps *must* extend at least 18" beyond the antenna. Fold the two sides of the 'tent' together to completely enclose the antenna and *securely* tape the foil to the fuselage (use a tape that won't damage the paint, such as masking tape).

Whatever you do, *do not leave an ELT/EPRIB in the alarm state unless ordered to do so by the IC/AFRCC*. You will have to consult your IC, AFRCC, and/or law enforcement to silence the ELT if the above methods are not practical.

Last but not least, ensure the aircraft owner is notified that the ELT was disabled. If you can't obtain a phone number, you can put a note on the aircraft (not a window) stating that the ELT has been disabled. Make your own notes and carry some in the aircraft.

10.10.1 Legal Issues

WASAR or CAP members will not enter private property and should not do anything that could cause harm or damage to the distress beacon or aircraft/boat. If entry is required the owner/operator or local law enforcement officials will make it.

A transmitting ELT is under the legal authority of the FCC, and federal law requires that it be deactivated ASAP. However, WASAR and CAP members *do not have the authority to trespass onto private property*, either to gain access to the aircraft or to enter the aircraft to gain access to the ELT. You must gain permission from the owner before you enter a private hangar or an aircraft. In some cases, especially at an airport, FBO personnel have permission to enter aircraft on the premises and can assist you.

While entry upon private property may be justified if such an act is for the purpose of saving life, every effort should be made to obtain the controlling agency's and/or the property owner's consent. If you need entry onto private property in order to search for an ELT, law enforcement authorities such as local police, the county sheriff's office or game wardens may be contacted for assistance.

Each state is the master of its own territory and appoints a chief SAR officer. Under a state-federal MOU, the AFRCC coordinates all inland SAR efforts. Note that 'coordinate' is not the same as 'command.' While AFRCC has legal authority to tell you to search someplace, the state SAR officer has legal authority to tell you NOT to.

The local civil authorities are in charge. In some states, the chief SAR officer may be the governor; in some it may be the state Adjutant General of the National Guard.

The FCC may issue warning letters, violation notices and fines, if appropriate in cases involving non-distress activations. However, if you run across a hoax or activation through gross negligence it should be reported to the nearest FCC field office.

Although not your responsibility, owners may ask you whether or not they can fly with a deactivated or inoperative ELT; the rules are found in FAR 91.207. An aircraft with an inoperable ELT can be ferried from a place where repairs or replacements cannot be made to a place where they can be made [91.207(3)(2)]. An aircraft whose ELT has been temporarily removed for repair can be flown if aircraft records contain an entry concerning the removal, a placard is placed in view of the pilot showing "ELT not installed," and the aircraft is not operated more than 90 days after the ELT was removed [91.207(f)(10)].

10.10.2 AFRCC information

You need to keep a log of the ELT search in order to provide certain information regarding the mission. This information will be given to the Incident Commander, and is required before AFRCC will close out the mission.

1. Date and time (Zulu) you left on the sortie.
2. Date and time the ELT was first heard.
3. Time in the search area and time enroute (hours and minutes; Hobbs).
4. Area(s) searched.
5. Actual location of the ELT, including latitude and longitude.
6. Date and time the ELT was located and silenced.
7. ELT model, manufacturer, serial number and battery expiration date.
8. Position in which you left the ELT switch: On, Off, or Armed.
9. Other (not required): 'N' or vessel number, make and model, owner information, and how the ELT was actuated.